Submission under the United Nations Framework Convention on Climate Change 2015

National Inventory Report

for the German Greenhouse Gas Inventory

1990 - 2013

Federal Environment Agency

UNFCCC Submission

This submission is made to meet the reporting requirements for national greenhouse gas inventories under the UNFCCC and EU regulation 525/2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change. The submission contains also parts of supplementary information to be included in the national inventory submission in accordance with the requirements under the Kyoto Protocol. However, as the CRF Reporter (in its most actual version 5.10) is not yet functional to allow for provision of emissions/removals under Article 3, paragraph without errors, the information provided under the Kyoto Protocol should be considered only as additional information, not as a formal national submission under the Kyoto Protocol.

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This report was produced in the framework of work of the National Co-ordination Agency (Single Entity) for the *National System of Emissions Inventories* (Nationales System Emissionsinventare; NaSE), sited within the Federal Environment Agency (UBA). Contributions for the chapters on agriculture, and on land use, land-use changes and forestry, were prepared by the Thünen Institute (TI).

The electronic version of this report, along with the pertinent emissions data in the Common Reporting Format (CRF) (Version 1.1, based on the CSE database, and with trend tables last revised as of 26 November 2013), is available on the Web site of the Federal Environment Agency:
http://www.umweltbundesamt.de/themen/klima-energie/klimaschutz-energiepolitik-in-deutschland/treibhausgas-emissionen

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AbfAblV	Ordinance on Environmentally Compatible Storage of Waste from Human Settlements and on Biological Waste-Treatment Facilities (Abfallablagerungsverordnung)
ABL	Old German Länder
AGEB	Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen)
AK	Working group (Arbeitskreis)
ALH	All other deciduous/broadleaf trees with high life expectancies (BWI tree-species group)
ALN	All other deciduous/broadleaf trees with low life expectancies (BWI tree-species group)
ANCAT	Abatement of Nuisances from Civil Air Transport
AR	Activity data (=AD)
ARD	Afforestation, reforestation, deforestation
ATKIS	Official topographic-cartographic information system (Amtliches Topographisch-Kartographisches Informationssystem)
AWMS	Animal Waste Management System
BAFA	Federal Office of Economics and Export Control
BAT	Best Available Technique
BDZ	Federal Association of the German Cement Industry (Bundesverband der Deutschen Zementindustrie)
BEF	Biomass-expansion factor

BEU	Balance of emissions sources for stationary and mobile combustion processes (Bilanz der Emissionsursachen für stationäre und mobile Verbrennungsprozesse)
BGR	Federal Institute for Geosciences and Raw Materials (Bundesanstalt für Geowissenschaften und Rohstoffe)
BGS	Fuel, gas and electricity industries of blast furnaces, steelworks and rolling mills; and forging plants, press works and hammer mills, including the various other plants (without their own coking plants) publicly connected to such operations
BGW	Federal Association of the German Gas and Water Industry (Bundesverband der deutschen Gas- und Wasserwirtschaft)
BHD	Diameter at breast height (= DBH; tree-trunk diameter at a height of 1.30 m above the ground)
BHKW	Combined heat and power (CHP) unit (Blockheizkraftwerk)
BKG	Federal Agency for Cartography and Geodesy (Bundesamt für Kartographie und Geodäsie)
BImSchV	Statutory Ordinance under the Federal Immission Control Act
BML	cf. BMEL
BMUB	Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
BMEL	Federal Ministry of Food and Agriculture
BMVEL	cf. BMEL
BMVG	Federal Ministry of Defence
BMWA	cf. BMWi
BMWi	Federal Ministry for Economic Affairs and Energy
BoHE	Main survey on soil use (Bodennutzungshaupterhebung)
BREF	BAT (Best Available Technique) Reference Documents
BSB	Biological oxygen demand (= BOD; Biologischer Sauerstoffbedarf)
BSB_5	Biological oxygen demand within 5 days (BOD_5)
BV Kalk	German Lime Association (Bundesverband der Deutschen Kalkindustrie)
BÜK	Soil-overview map (Bodenübersichtskarte)
BWI	National Forest Inventory (Bundeswaldinventur)
BZE	Forest Soil Inventory (Bodenzustandserhebung im Wald)
C_2F_6	Hexafluorethane
CAPIEL	Coordinating Committee for the Associations of Manufacturers of Industrial Electrical Switchgear and Controlgear in the European Union
CFC	Chlorofluorocarbons (= Fluorchlorkohlenwasserstoffe (FCKW))
CFI	Continuous Forest Inventory
CH_4	Methane
C_{org}	Organic carbon stored in the soil
CO	Carbon monoxide
CO_2	Carbon dioxide
CORINAIR	Coordination of Information on the Environment, sub-project: Air
CORINE	Coordinated Information on the Environment
CRF	Common Reporting Format
CSB	Chemical oxygen demand (COD)
D	Germany (Deutschland)

DBFZ	Deutsches Biomasseforschungszentrum (German centre for biomass research)
DEHSt	German Emissions Trading Authority (Deutsche Emissionshandelsstelle)
DESTATIS	Federal Statistical Office (official abbreviation: StBA)
DFIU	Franco-German Institute for Environmental Research, at the University of Karlsruhe (Deutsch-Französisches Institut für Umweltforschung an der Universität Karlsruhe)
DG	Landfill gas (Deponiegas)
DGMK	German Association of Oil, Natural Gas and Coal Science (Deutsche Wissenschaftliche Gesellschaft für Erdöl, Erdgas und Kohle eV.)
DIN	DIN standard (Deutsche Industrienorm)
DIW	German Institute for Economic Research (Deutsches Institut für Wirtschaftsforschung)
DLR	German Aerospace Center (Deutsches Zentrum für Luft- and Raumfahrt)
DMKW	Diesel-engine power stations (Dieselmotorkraftwerke)
D_N	Nitrogen in wastewater
DOC	Degradable organic carbon Degradable organic carbon)
DOC_F	Fraction of DOC dissimilated (converted into landfill gas) Fraction of DOC dissimilated)
DSWF	"Forest Fund Database" for the former GDR (Datenspeicher Waldfonds)
DTKW	Steam-turbine power stations (Dampfturbinenkraftwerke)
DVGW	German Association of the Gas and Water Industry (Deutsche Vereinigung des Gas- und Wasserfachs eV.)
D7	Tree-trunk diameter at a height of 7 m above the ground
EBZ	Energy Balance line in the BEU (Energiebilanzzeile)
EEA	European Environment Agency
EECA	European Electronic Component Manufacturers Association
EEG	Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz); promulgated in Federal Law Gazette Part I No. 40 of 31 July 2004, p. 1918 ff.)
EF	Emission factor
EI	Emission index = emission factor
E_{KA}	Inhabitant connected to wastewater-treatment system (Einwohner mit Kläranlagenanschluss)
EL	Fuel oil EL (EL = easily liquid)
EM	Emission
EMEP	Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe
EMEV	Emissions-relevant energy consumption (Emissionsrelevanter Energieverbrauch)
ERT	Expert Review Team
ESIA	European Semiconductor Industry Association
ETS	EU Emissions Trading Scheme
EU	European Union
EU-EH	ETS (Europäischer Emissionshandel)
EUROCONTROL	European Organisation for the Safety of Air Navigation
EUROSTAT	Statistical Office of the European Communities

EW	Population (Einwohnerzahl)
FA	Combustion systems (Feuerungsanlagen)
FAP	Specialised contact person in the NaSe (Fachlicher Ansprechpartner)
FAL	Federal Agricultural Research Centre
FAO	United Nations Food and Agriculture Organisation of the United Nations
FCKW	CFC (Fluorchlorkohlenwasserstoffe)
F gases	Fluorinated greenhouse gases
FHW	District heating stations (Fernheizwerke)
FKW	Perfluorocarbons (PFC)
FKZ	Research project number (Forschungskennzahl)
FV	Responsible expert (Fachverantwortlicher) in the NaSE
FWL	Thermal output from combustion (Feuerungswärmeleistung)
GAS-EM	GASeous EMissions (programme for calculation of agricultural emissions)
GEREF	GERman Emission Factor Database
GFA	Large combustion systems (Großfeuerungsanlagen)
GG	Total weight (Gesamtgewicht)
GIS	Gas-insulated switching systems
GMBL	Joint Ministerial Gazette (Gemeinsames Ministerialblatt)
GMES	Global Monitoring for Environment and Security
GMKW	Gas-engine power stations (Gasmotorkraftwerke)
GPG	Good Practice Guidance
GSE FM-INT	GMES Services Elements Forest Monitoring: Inputs for national greenhouse-gas reporting
GT	Gas turbines
GTKW	Gas-turbine power stations (Gasturbinenkraftwerke)
GuD	Gas and steam turbine power stations (Gas- und Dampfturbinenkraftwerke)
GWP	Global Warming Potential
HFC	Hydrofluorocarbons (= HFKW)
HFCKW	Hydrochlorofluorocarbons (HCFCs; Wasserstoffhaltige Fluorchlorkohlenwasserstoffe)
HFKW	Hydrofluorocarbons (HFC)
HK	Key category (Hauptkategorie); is applied to both emissions sources and sinks
HS-GIS	High-voltage gas-insulated switching systems
IAI	International Aluminium Institute
IE	Included elsewhere
IEA	International Energy Agency
IEF	Implied emission factor
IfE	Institute for Energy and Environment (Institut für Energetik und Umwelt)
IFEU	Institute for Energy and Environmental Research (Institut für Energie- und Umweltforschung)
IKW	Industrial power stations (Industriekraftwerke)
IMA	Interministerial Working Group (Interministerielle Arbeitsgruppe)
IPCC	Intergovernmental Panel On Climate Change
IS08	Inventory Study 2008 (Inventurstudie 2008)
K	Fuel input for power generation (direct drive)
k.A.	No entry (keine Angabe)

KP	Kyoto Protocol
KS	Sewage sludge (Klärschlamm)
l	Level (= Level assessment pursuant to IPCC Good Practice Guidance)
LF	Agriculturally used land (landwirtschaftlich genutzte Flächen)
LKW	Truck (Lastkraftwagen)
LTO	Landing/take-off cycle
LUCF	Land Use Change and Forestry
LULUCF	Land Use, Land Use Change and Forestry
MBA	Mechanical-biological waste treatment (MBT; Mechanisch-Biologische Abfallbehandlung)
MCF	Methane Conversion Factor
MS	Medium voltage (Mittelspannung)
MSW	Municipal solid waste
MVA	Waste incineration plant (Müllverbrennungsanlage)
MW	Megawatt
N	Nitrogen
N_2O	Nitrous oxide (laughing gas)
NA	Not applicable
NASA	National Aeronautics and Space Administration
NaSE	German National System of Emissions Inventories (Nationales System Emissionsinventare)
NBL	New German Länder (neue Bundesländer)
NE	Not estimated
NEAT	Non-energy Emission Accounting Tables
NEC	Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain air pollutants National Emission Ceilings).
NEV	Non-energy-related consumption (nichtenergetischer Verbrauch)
NF_3	Nitrogen trifluoride
NFR	New Format on Reporting, Nomenclature for Reporting to the UN ECE
NFZ	Utility vehicles (Nutzfahrzeuge)
NH_3	Ammonia
NIR	National Inventory Report
NMVOC	Non-Methane Volatile Organic Compounds
NO	Not occurring
NO	Nitrogen monoxide
NSCR	Non-selective catalytic reduction
OCF	One-component foam (installation foam)
OX	Oxidation factor
PAH	Polycyclic aromatic hydrocarbons (= PAK)
PAK	Polycyclic aromatic hydrocarbons (Polycyclische aromatische Kohlenwasserstoffe; = PAH)
PARTEMIS	Measurement and prediction of emissions of aerosols and gaseous precursors from gas turbine engines
PCDD/F	Polychlorinated dibenzo-dioxins/- furans
PF	Process combustion (Prozessfeuerungen)
PFC	Perfluorocarbons (= FKW)

PKW	Automobile (Personenkraftwagen)
PU	Polyurethane
QK	Quality control (QC; Qualitätskontrolle)
QS	Quality assurance (QA; Qualitätssicherung)
QSE	Quality System for Emissions Inventories
REA	Flue-gas desulphurising plant (Rauchgasentschwefelungsanlage)
ROE	Oil equivalent (OE; Rohöleinheit)
RSt	Raw steel
RWI	Rheinisch-Westfälisches Institut für Wirtschaftsforschung
S	Fuel input for power generation
S	Heating oil, heavy (high viscosity; "Heizöl S")
S&A Report	Synthesis and Assessment Report
SA	Heating oil, heavy (high viscosity; low sulphur content; "Heizöl SA")
SE	Sampling error
SF_6	Sulphur hexafluoride
SKE	Hard-coal units (Steinkohleneinheiten)
SNAP	Selected Nomenclature for Air Pollution
SO_2	Sulphur dioxide
StBA	Federal Statistical Office (Statistisches Bundesamt Deutschland)
STEAG	STEAG Aktiengesellschaft (a large power producer in Germany)
T	Trend (= trend assessment pursuant to IPCC Good Practice Guidance, in the source-category overview tables)
TA Luft	Technical directive on air quality control; First General Administrative Provision on the Federal Immission Control Act (Clean Air Directive; Technische Anleitung zur Reinhaltung der Luft)
TAN	Total Ammoniacal Nitrogen
THG	Greenhouse gases (GHG; Treibhausgase)
TI	Johann Heinrich von Thünen Institute
TI-AK	Johann Heinrich von Thünen Institute, Institute of Climate-Smart Agriculture (Institut für Agrarklimaschutz)
TI-WO	Johann Heinrich von Thünen Institute, Institute of Forest Ecosystems (Institute für Waldökosysteme)
TM	Dry matter (Trockenmasse)
TOC	Total Organic Carbon
TREMOD	Traffic Emission Estimation Model
TS	Siccative (Trockenstoff)
TÜV	Technischer Überwachungsverein (Certifying body for technical and product safety)
TVF	Tonne of utilisable production (Tonne verwertbare Förderung)
UBA	Federal Environment Agency (Umweltbundesamt)
UN ECE	United Nations Economic Commission for Europe
UN FCCC	United Nations Framework Convention on Climate Change
UN	United Nations
UStatG	Environmental Statistics Act (Umweltstatistikgesetz)
VDEh	German Iron and Steel Institute (Verein Deutscher Eisenhüttenleute; in 2003, renamed "Stahlinstitut VDEh")
VDEW	Electricity Industry Association (Verband der Elektrizitätswirtschaft)

VDI	Association of German Engineers (Verein Deutscher Ingenieure e.V.)
VDN	Association of German network operators (Verband der Netzbetreiber e.V.)
VDZ	German Cement Works Association (Verein Deutscher Zementwerke e.V.)
VGB	Technical association of operators of large power stations (Technische Vereinigung der Großkraftwerksbetreiber e.V.)
VIK	Association of the Energy and Power Industry (Verband der Industriellen Energie- and Kraftwirtschaft e.V.)
VOC	Volatile Organic Compounds
VS	Volatile Solids
W	Fuel input for heat generation
WS	Portion of a specific wastewater treatment system (e.g. aerobic, anaerobic)
WZ	Economic activity listed in the National Classification of Economic Activities (NACE; Wirtschaftszweig)
XPS	Extruded polystyrene
ZSE	Central System of Emissions (CSE)

Units and sizes

Multiplication factors, abbreviations, prefixes and symbols

		Prefix/symbol	
Multiplication factor	Abbreviation	Name	Symbol
1,000,000,000,000,000	10^{15}	peta	P
1,000,000,000,000	10^{12}	tera	T
1,000,000,000	10^{9}	giga	G
1,000,000	10^{6}	mega	M
1,000	10^{3}	kilo	k
100	10^{2}	hecto	h
0.1	10^{-1}	deci	d
0.01	10^{-2}	centi	c
0.001	10^{-3}	milli	m
0.000001	10^{-6}	micro	µ

Units and abbreviations

Abbreviation	Units
°C	degrees Celsius
a	year
cal	calorie
g	gram
h	hour
ha	hectare
J	joule
m^3	cubic metre
ppm	parts per million
t	tonne
W	watt

Standard conversions

Units	is equivalent to
1 tonne (t)	1 megagram (Mg)
1 kilotonne / thousand tonnes (kt)	1 gigagram (Gg)
1 megatonne / million tonnes (Mt)	1 teragram (Tg)

Reading the introductory information tables

The introductory information tables appear at the beginning of each source category chapter. Each such table provides an overview of the relevant category's importance and of the methods used in connection with it.

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T	**1.A.1.c Manufacture of Solid Fuels and Other Energy Industries**	**All fuels**	**CO_2**	**65,289.0**	**(5.36%)**	**10,267.5**	**(1.10%)**	**-84.3%**
-/-	1.A.1.c Manufacture of Solid Fuels and Other Energy Industries	All fuels	N_2O	659.2	(0.05%)	150.1	(0.02%)	-77.2%
-/-	1.A.1.c Manufacture of Solid Fuels and Other Energy Industries	All fuels	CH_4	92.0	(0.01%)	13.9	(0.00%)	-84.9%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	Tier 2	NS	CS
N_2O	Tier 2	NS	CS
NO_X, CO, NMVOC, SO_2			CS

Key category

The upper section of the table shows the key-category-analysis lines that are relevant for the category in question; the emissions, as an absolute figure (kt CO_2 equivalent) and as a percentage of total emissions in 1990 and in the last reported year; and the pertinent emissions trend between the base year (1990 or 1995 for the F gases) and the last reported year. In the German-language version of the NIR, the term "Hauptkategorie" is used synonymously with the term "key category".

L = Key category in terms of emissions level
T = Key category in terms of emissions trend
2 = Key category pursuant to Tier-2 analysis

Gas

The lower section of the table provides information about the methods used, the source for the activity data and the emission factors (EF) used.

Method used

D = IPCC default
RA = Reference Approach
Tier 1 = IPCC tier 1
Tier 2 = IPCC tier 2
Tier 3 = IPCC tier 3
C = CORINAIR
CS = Country-specific
M = Model

Source for the activity data

M = Model
Q = Questionnaires, surveys
PS = Plant-specific data
AS = Associations, business organizations
RS = Regional statistics
NS = National statistics
IS = International statistics

Emission factor (EF)

D = IPCC default
C = CORINAIR
CS = Country-specific
PS = Plant-specific
M = Model

0 SUMMARY (ES)

As a Party to the United Nations Framework on Climate Change (UNFCCC), since 1994 Germany has been obliged to prepare, publish and regularly update national emission inventories of greenhouse gases. In February 2005, the Kyoto Protocol entered into force. As a result, the international community of nations is required to implement binding action objectives and instruments for global climate protection. This leads to very extensive and detailed obligations vis-à-vis the preparation, reporting and review of emissions inventories. In keeping with Article 3 of the Kyoto Protocol, the EU countries have been making use of the option of jointly fulfilling obligations under the Kyoto Protocol and the UN Framework Convention on Climate Change. They have been doing so via European regulations, most recently EU Regulation 525/2013[1] and its Implementing Regulation 749/2014[2]. Current European implementation of the Kyoto Protocol, via regulations, has made the Protocol's provisions legally binding for Germany.

Pursuant to Decision 24/CP.5, all Parties listed in ANNEX I of the UNFCCC are required to prepare and submit annual National Inventory Reports (NIRs) containing detailed and complete information on the entire process of preparation of such greenhouse-gas inventories. The purpose of such reports is to ensure the transparency, consistency and comparability of inventories and support the independent review process.

Pursuant to to decision 15/CMP.1, as of 2010 all of the countries listed in ANNEX I of the UN Framework Convention on Climate Change that are also parties to the Kyoto Protocol must submit annual inventories in order to be able to make use of flexible mechanisms pursuant to Articles 6, 12 and 17 of the Kyoto Protocol.

Together with the inventory tables, Germany submits a National Inventory Report (NIR), which refers to the period covered by the inventory tables and describes the methods and data sources on which the pertinent calculations are based. The report, and the report tables in the Common Reporting Format (CRF), have been prepared pursuant to the UNFCCC guidelines on annual inventories (FCCC/CP/2013/10/Add.3) and in conformance with the 2006 IPCC Guidelines for national Greenhouse Gas Inventories (IPCC Guidelines, 2006) and the IPCC Good Practice Guidance (IPCC-GPG, 2000). The NIR contains a Part II, along with additional sub-chapters, that fulfill the expanded requirements under the Kyoto Protocol and the relevant obligations at the European level.

Part I of the NIR comprising Chapters 1 to 10, contains all the information relevant to the annual greenhouse-gas inventory.

Chapter 1 provides background information about climate change and about greenhouse-gas inventories, as well as further information relative to the Kyoto Protocol. This section describes the National System pursuant to Article 5.1 of the Kyoto Protocol, which system is designed to aid and assure compliance with all reporting obligations with respect to atmospheric emissions and removals in sinks. In addition, this chapter describes the basic principles and methods

[1] REGULATION (EU) No 525/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 May 2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC

[2] COMMISSION IMPLEMENTING REGULATION (EU) No 749/2014 of 30 June 2014 on structure, format, submission processes and review of information reported by Member States pursuant to Regulation (EU) No 525/2013 of the European Parliament and of the Council

with which the emissions and sinks of the IPCC categories are calculated, presents a short summary of key-category assessment and describes the Quality System for Emissions Inventories (QSE). The chapter concludes with sections on uncertainties analysis and completeness analysis.

Chapter 2 provides a general overview of development of emissions of direct and indirect greenhouse gases and of removals of carbon dioxide in sinks.

Chapters 3 through 9 present information about the individual source and sink groups. Along with general descriptions and information relative to the methods used, sub-chapters in this section also include information about pertinent uncertainties, quality assurance and quality control, recalculations carried out and planned improvements for relevant source and sink categories.

The inventories, the National System and the Quality System for Emissions Inventories have all been further improved in keeping with the results of the reviews that have taken place in recent years. More-detailed information about recalculations, and information relative to the improvements and changes made with regard to the last greenhouse-gas inventory, is presented in **Chapter 10** .

Part II of the NIR, comprising **Chapters 11 to 16**, presents the so-called "Kyoto-NIR", in fulfillment of the expanded requirements for Kyoto reporting, and in keeping with the required organisation (annotated NIR).

Chapter 11 contains all information relative to Kyoto reporting in the areas of land use, land-use changes and forestry (LULUCF), especially the definition of "forest" chosen, details on the land-classification technique used and all information relative to selected activities pursuant to Arts. 3.3 and 3.4 of the Kyoto Protocol.

Chapter 12 is devoted completely to accounting for Kyoto units, a process for which, in Germany, the German Emissions Trading Authority (DEHSt) is responsible.

Chapters 13 and 14 provide an overview of changes made in the National System, and at the German Emissions Trading Authority, with the aim of ruling out the possibility of any undue influences on Kyoto reporting.

Chapter 15 lists all the measures that Germany is taking to minimise negative impacts pursuant to Article 3 (14).

Chapter 16 presents any required further information relative to Kyoto reporting.

Annexes 1 through 7, comprising **Chapters 17-23**, contain more-detailed descriptions of key categories, of individual source categories, of the CO_2-reference procedure, of completeness issues, of the National System and the Quality System, of the CSE emissions database and of uncertainties.

More-detailed information about specific relevant issues is presented in the literature listed in **Chapter 24**.

The Federal Environment Agency makes all calculations for the greenhouse-gas inventory and carries out all relevant compilation. Data on emissions and sinks in the land use, land-use changes and forestry sector have been provided by the Johann Heinrich von Thünen Institute (TI).

In the current year, nearly all reference parameters and methodological specifications for inventory calculation and reporting (use of the new 2006 IPCC Guidelines, changes in allocations, inclusion of new emission sources, use of new GWP values, the lack of a comparable reference inventory for 2012, etc.) have changed. As a result, it is not possible to quantify and document the effects of recalculations in relation to the inventory values reported last year. Hier wird erst mit der nächsten Berichterstattung wieder das Detail und der geforderte Standard möglich.

0.1 Background information on greenhouse-gas inventories and climate change (ES.1)

0.1.1 Background information about climate change (ES1.1)

Ever since the start of industrialisation, significant trans-regional and global changes in the substance balance of the atmosphere have been observed as a consequence of human activities. Worldwide, concentrations of carbon dioxide (CO_2) have risen by approximately 43 % compared to their levels in pre-industrial times, whilst those of methane (CH_4) have increased by 150 % and those of nitrous oxide (N_2O) have risen by 20 %. Furthermore, a number of brand-new substances – i.e. substances that for all intents and purposes do not occur in nature and are produced almost exclusively by humans – such as chlorofluorocarbons (CFCs), halons, perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3) have entered the atmosphere. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)[3] shows that human impacts on climate are scientific fact.

0.1.2 Background information about greenhouse-gas inventories (ES1.2)

In February 2005, the Kyoto Protocol entered into force. As a result, the international community of nations is required to implement binding action objectives and instruments for global climate protection. In the first commitment period, which lasted from 2008 through 2012, the European Community (at the time, with 15 Member States) committed itself to reducing its greenhouse-gas emissions by 8 % with respect to the base year (1990 and 1995[4]). This commitment has been divided and fulfilled within the EU in the framework of a burden-sharing agreement between the participating Member States[5]. In that agreement, Germany agreed to reduce its emissions by 21 % in comparison to the base year and thus agreed to make a substantial contribution to fulfillment of the EU's commitment. With a 25.8 % reduction by 2012, Germany reached and considerably exceeded that goal.

In the framework of the now-commenced second commitment period of the Kyoto Protocol, the European countries have committed themselves to reducing their greenhouse-gas emissions by 20 % by 2020. At the same time, they have announced that, under certain

[3] IPCC Fifth Assessment Report: Climate Change 2007, available in the Internet at: http://www.ipcc.ch/ipccreports/assessments-reports.htm

4 For HFC, PFC and SF_6

5 Burden-sharing agreement, adopted with Council Decision 2002/358/EC of 25 April 2002 concerning the approval, on behalf of the European Community, of the Kyoto Protocol to the United Nations Framework Convention on Climate Change and the joint fulfilment of commitments thereunder [OJ L 130 of 15 May 2002]

conditions, this European contribution could be increased to a 30 %[6] reduction with respect to 1990.

On 3 December 2014, Germany's federal cabinet adopted the Climate Action Programme 2020[7]. With this move, the Federal Government is ensuring that Germany will reduce its greenhouse-gas emissions by 40 %, with respect to 1990, by 2020.

0.1.3 Background information relative to supplementary information as required pursuant to Article 7 (1) of the Kyoto Protocol (ES.1.3)

The present report, in keeping with decision 15/CMP.1, presents, for the first time, supplementary information pursuant to Article 7 (1) of the Kyoto Protocol, for support of the review process under the Kyoto Protocol. This information includes:

- General information on inventory preparation in connection with reporting pursuant to Article 3 (3) Kyoto Protocol and for the selected additional activities pursuant to Article 3 (4) Kyoto Protocol; (cf. Chapter 8)
- Information regarding the certificates under the Kyoto Protocol in connection with decisions 13/CMP.1 and 5/CMP.1; (cf. Chapter 8)
- Information regarding changes in the National System of emissions reporting pursuant to Article 5 (1) of the Kyoto Protocol; (cf. Chapter 13)
- Information regarding changes in the National Registry; (cf. Chapter 12)
- Information regarding minimisation of negative impacts pursuant to Article 3 (14) of the Kyoto Protocol; (cf. Chapter 15)

0.2 Combined greenhouse-gas emissions, their removals in sinks, and emissions and removals from KP-LULUCF activities (ES.2)

0.2.1 Greenhouse-gas inventory (ES.2.1)

In the relevant interval, 2008 through 2012, Germany completely fulfilled its obligations within the framework of the aforementioned European obligation, with regard to the base-year emissions determined in 2007[8]. It did this by achieving a reduction of 1,232,429.543 Gg (CO_2 equivalent). In the following year, 2013, emissions increased by 2.4 % with respect to 2012. This was triggered primarily by cold winter weather, which increased carbon dioxide emissions from the Residential sector and the Commerce, Trade and Services sector (cf. Chapter 2.1).

[6] Information on the quantified emission limitation or reduction objectives (QELROs) for the second commitment period under the Kyoto Protocol; SUBMISSION BY DENMARK AND THE EUROPEAN COMMISSION ON BEHALF OF THE EUROPEAN UNION AND ITS MEMBER STATES, Copenhagen, 19 April 2012

[7] http://www.bmub.bund.de/themen/klima-energie/klimaschutz/nationale-klimapolitik/aktionsprogramm-klimaschutz/

[8] The reference figures for determining achievement of reduction obligations under the Kyoto Protocol have been defined in keeping with results of the review, carried out in 2007, of the initial report and of reporting for 2006 pursuant to Article 8 of the Kyoto Protocol. Pursuant to its obligations under the Kyoto Protocol and EU burden sharing (Council Decision 2002/358/EC), Germany's reduction obligations amount to 21 %.

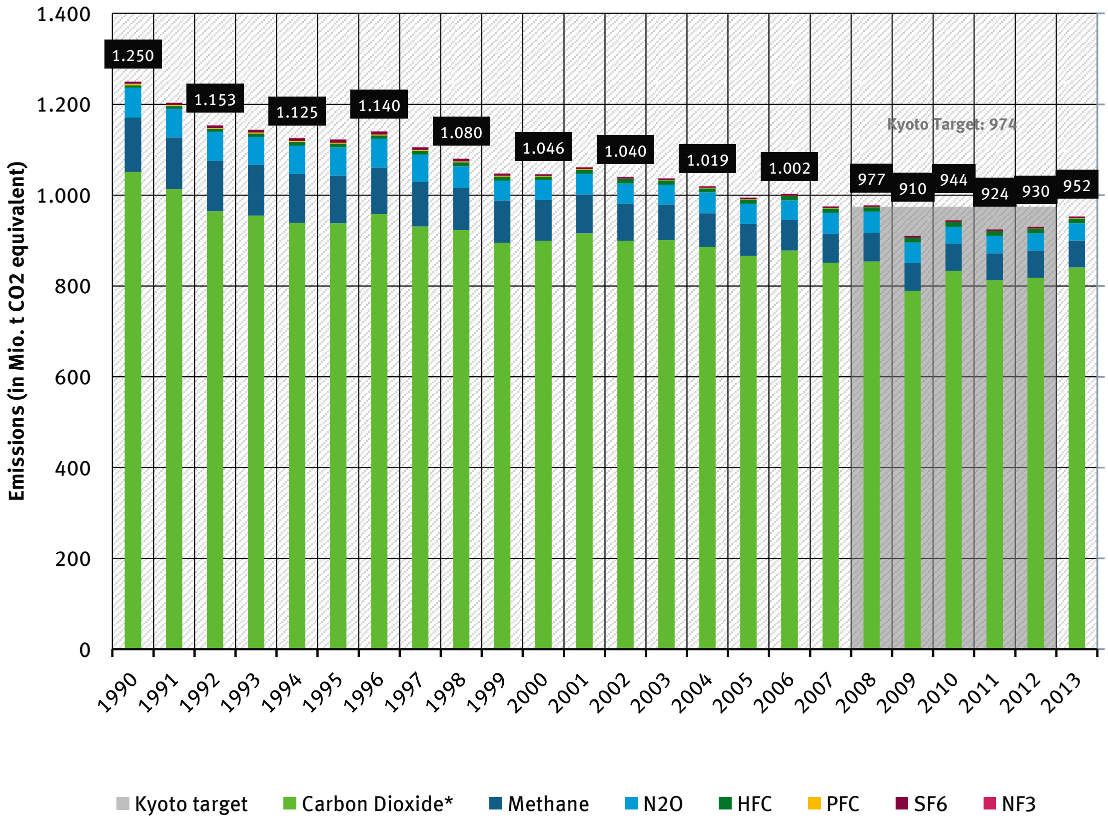


Figure 1: Development of greenhouse gases in Germany since 1990, by greenhouse gases [9,]

The individual greenhouse gases contributed to this development to varying degrees (cf. Table 1). This is hardly surprising given that, in any given year the various greenhouse gases account for varying proportions of total emissions (cf. Table 2). Detailed tables are provided in Annex Chapter 22.3.

In 2013, with an 88.3 % share, carbon dioxide emissions again accounted for the largest share of greenhouse-gas emissions. Most of the carbon dioxide is released via stationary and mobile combustion of fossil fuels. As a result of a disproportionately large reduction of other greenhouse-gas emissions, CO_2 emissions' share of total emissions has increased by over 4 percentage points since the base year. Methane (CH_4) emissions, caused predominantly by animal husbandry, fuel distribution and landfills, accounted for a 6.2 % share. Emissions of nitrous oxide (N_2O), caused primarily by agriculture, industrial processes and burning of fossil fuels, contributed 4.0 % of greenhouse-gas releases. The fluorinated greenhouse gases (the so-called "F gases") accounted for about 1.5 % of total emissions. NF_3, a greenhouse gas that is now being reported for the first time, accounts for a negligible share of only 0.002 %. The distribution of greenhouse-gas emissions in Germany is typical for a highly developed and industrialised country.

Information about the relevant trends is provided in Chapter 2, while all detailed tables relative to discussion of trends are provided in Annex Chapter 22.3.

[9] CO_2 emissions from, and removals in, soils are reported under land-use changes and forestry.

Table 1: Emissions trends in Germany, by greenhouse gas and source category

Emissions Trends (kt CO_2 equi.)	**1990**	**1995**	**2000**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Net CO_2 emissions/removals	1,016,520	902,060	858,304	852,040	863,457	836,766	832,524	768,407	813,702	793,809	800,397	823,125
CO_2 emissions (without LULUCF)	1,050,885	938,024	899,386	865,931	877,971	850,861	854,061	789,107	833,112	812,665	817,913	840,605
CH_4	119,742	105,288	89,952	70,682	66,717	64,247	63,438	61,215	60,352	59,279	60,082	59,475
N_2O	65,825	61,723	43,729	44,001	43,735	45,623	46,080	45,271	37,247	38,543	37,728	38,104
HFC (1995 base year)	5,754	8,354	8,020	9,581	9,784	9,885	10,081	10,660	10,242	10,485	10,710	10,742
PFC (1995 base year)	3,060	2,086	956	837	668	586	565	405	344	277	241	257
SF_6 (1995 base year)	4,428	6,467	4,072	3,320	3,242	3,181	2,971	2,924	3,047	3,163	3,155	3,261
NF_3 (1995 base year)	7	5	9	34	28	12	30	29	61	61	35	17
Total Emissions/Removals with LULUCF (CO_2 equivalent)	**1,215,336**	**1,085,983**	**1,005,043**	**980,495**	**987,631**	**960,301**	**955,688**	**888,910**	**924,996**	**905,616**	**912,348**	**934,980**
Total Emissions without CO_2 from LULUCF (CO_2 equivalent)	**1,249,701**	**1,121,948**	**1,046,125**	**994,386**	**1,002,144**	**974,395**	**977,226**	**909,609**	**944,406**	**924,472**	**929,864**	**952,460**
Emission source and sink categories [10] (kt CO_2 equi.)	**1990**	**1995**	**2000**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
1. Energy	1,037,165	918,693	873,037	834,623	844,150	817,163	822,663	764,675	804,208	782,862	790,281	813,439
2. Industrial Processes	96,404	97,366	76,950	74,929	75,672	76,754	72,962	65,200	62,381	62,943	62,067	61,372
3. Agriculture	77,889	67,653	67,160	63,046	62,121	61,506	63,802	63,100	62,260	63,847	63,398	64,243
4. Land-Use Change and Forestry	-32,531	-34,168	-39,316	-12,199	-12,809	-12,383	-19,814	-18,962	-17,662	-17,098	-15,745	-15,694
CO2 (net emissions)	*-34,365*	*-35,965*	*-41,082*	*-13,891*	*-14,513*	*-14,094*	*-21,538*	*-20,699*	*-19,410*	*-18,856*	*-17,516*	*-17,481*
N2O & CH4	*1,834*	*1,797*	*1,767*	*1,693*	*1,704*	*1,711*	*1,723*	*1,737*	*1,748*	*1,758*	*1,771*	*1,787*
5. Waste	36,409	36,439	27,211	20,096	18,496	17,260	16,076	14,897	13,809	13,062	12,347	11,620

Table 2: Contributions to emissions trends in Germany, by greenhouse gas and source category

GHG Emission Fractions (%)	**1990**	**1995**	**2000**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
CO_2 emissions (without LULUCF)	84.09	83.61	85.97	87.08	87.61	87.32	87.40	86.75	88.22	87.91	87.96	88.26
CH_4	9.58	9.38	8.60	7.11	6.66	6.59	6.49	6.73	6.39	6.41	6.46	6.24
N_2O	5.27	5.50	4.18	4.42	4.36	4.68	4.72	4.98	3.94	4.17	4.06	4.00
HFC	0.46	0.74	0.77	0.96	0.98	1.01	1.03	1.17	1.08	1.13	1.15	1.13
PFC	0.24	0.19	0.09	0.08	0.07	0.06	0.06	0.04	0.04	0.03	0.03	0.03
SF_6	0.35	0.58	0.39	0.33	0.32	0.33	0.30	0.32	0.32	0.34	0.34	0.34
NF_3	0.0006	0.0005	0.0009	0.0035	0.0028	0.0012	0.0030	0.0032	0.0065	0.0066	0.0038	0.0018
GHG Emission Fractions for Categories (%)	**1990**	**1995**	**2000**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
1. Energy	82.99	81.88	83.45	83.93	84.23	83.86	84.18	84.07	85.15	84.68	84.99	85.40
2. Industrial Processes	7.71	8.68	7.36	7.54	7.55	7.88	7.47	7.17	6.61	6.81	6.67	6.44
3. Agriculture	6.23	6.03	6.42	6.34	6.20	6.31	6.53	6.94	6.59	6.91	6.82	6.74
4. Land-Use Change and Forestry (N_2O & CH_4)	0.15	0.16	0.17	0.17	0.17	0.18	0.18	0.19	0.19	0.19	0.19	0.19
5. Waste	2.91	3.25	2.60	2.02	1.85	1.77	1.65	1.64	1.46	1.41	1.33	1.22

[10] Informationen on the structure of the Common Reporting Format (CRF): http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch1ri.pdf

0.2.2 KP-LULUCF activities (ES.2.2)

In comparison to their level in 2012, removals of CO_2 under Article 3.3 increased by 12 % (with respect to the total sum of CO_2 emissions – 3503.5 kt – in 2013 from A/R & D activities).

Under Article 3.4, activities relative to harvested wood products (HWP), and cropland and grazingland management, are now included along with the activity forest management. In the area of cropland management, CO_2 emissions increased slightly (2% with respect to 13335.9 kt CO_2 for 2013) with respect to the previous year, 2012. The emissions and removals in the other areas have hardly changed at all over the past three years. With regard to total emissions, and also taking account of the other GHG, a 3 % reduction in sinks was determined with respect to the previous year, 2012.

0.3 Combined emissions estimates, and trends for source and sink groups, including KP-LULUCF activities (ES.3)

0.3.1 Greenhouse-gas inventory (ES.3.1)

Figure 2 shows the contributions of individual source and sink categories to total greenhouse-gas emissions. It highlights the considerable constancy of the relative shares of the various source and sink categories and the absolute predominance of energy-related emissions. On the other hand, absolute energy-related emissions have continuously decreased over time. The variations that are superimposed over this trend are largely temperature-related. Because temperatures – especially in winter – affect heating patterns, they also affect energy consumption for heating, and thus they have major impacts on annual trends in energy-related CO_2 emissions.

On the whole, greenhouse-gas emissions have decreased by 24.0 % since 1990. Considerations of the various components involved confirm this trend, to varying degrees. With respect to the base-year emissions (in 1995 for the F gases & NF_3; otherwise, in 1990), the relevant emissions changes for the most important greenhouse gases in terms of quantity were as follows: - 20.0 % for carbon dioxide (CO_2), - 50.3 % for methane (CH_4) and - 42.1 % for nitrous oxide (N_2O). The corresponding trends for the so-called "F" gases, which contribute about 1.5 % of greenhouse-gas emissions overall, have not been as clearly similar to each other, however. In keeping with the introduction of new technologies, and with use of these substances as substitutes, since base year 1995 SF_6 emissions decreased by 49.6 % and PFC emissions dropped by 87.7 %, while HFC emissions increased by 28.6 %. Emissions of NF_3, a new greenhouse gas that has to be reported, have increased considerably since 1995: +216.1%. That gas's contribution to total emissions is exceedingly small, however.

With respect to the previous year, 2012, total emissions increased considerably, by 2.4 %, primarily as a result of weather-related increases in CO_2 emissions from the Residential (+16.2%) and Commercial and Institutional (commerce, trade and services) (+9.8%) sectors.

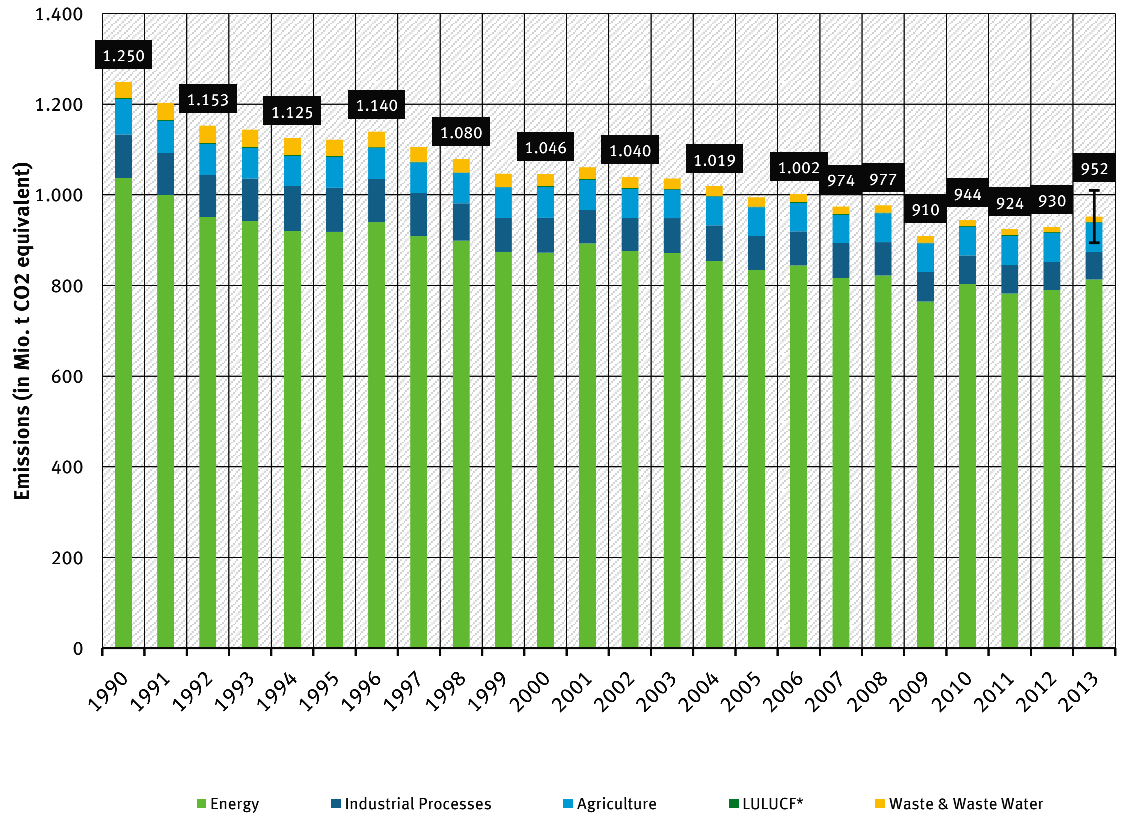


Figure 2: Emissions trends in Germany since 1990, by categories[11]

Figure 3 shows the relative developments of emissions from categories since 1990. The most significant reduction occurred in the area of waste emissions. Increased recycling of recyclable materials (Packaging Ordinance), and reuse of materials as compost (Biowaste Ordinance), have led to a sharp reduction in the quantity of waste that is landfilled and hence to continuous reductions in landfill emissions. Emissions-reducing measures carried out in 1997 and 2009 in the sector of adipic-acid production had major impacts on emissions from industrial processes. Emissions from solvent and other product use decreased markedly, as a result of decreased narcotic use of N_2O. The development of emissions from agriculture essentially follows the development of livestock data. A detailed discussion of emissions trends is presented in Chapter 2, Trends in Greenhouse Gas Emissions.

[11] CO_2 emissions from, and removals in, soils are reported under land-use changes and forestry.

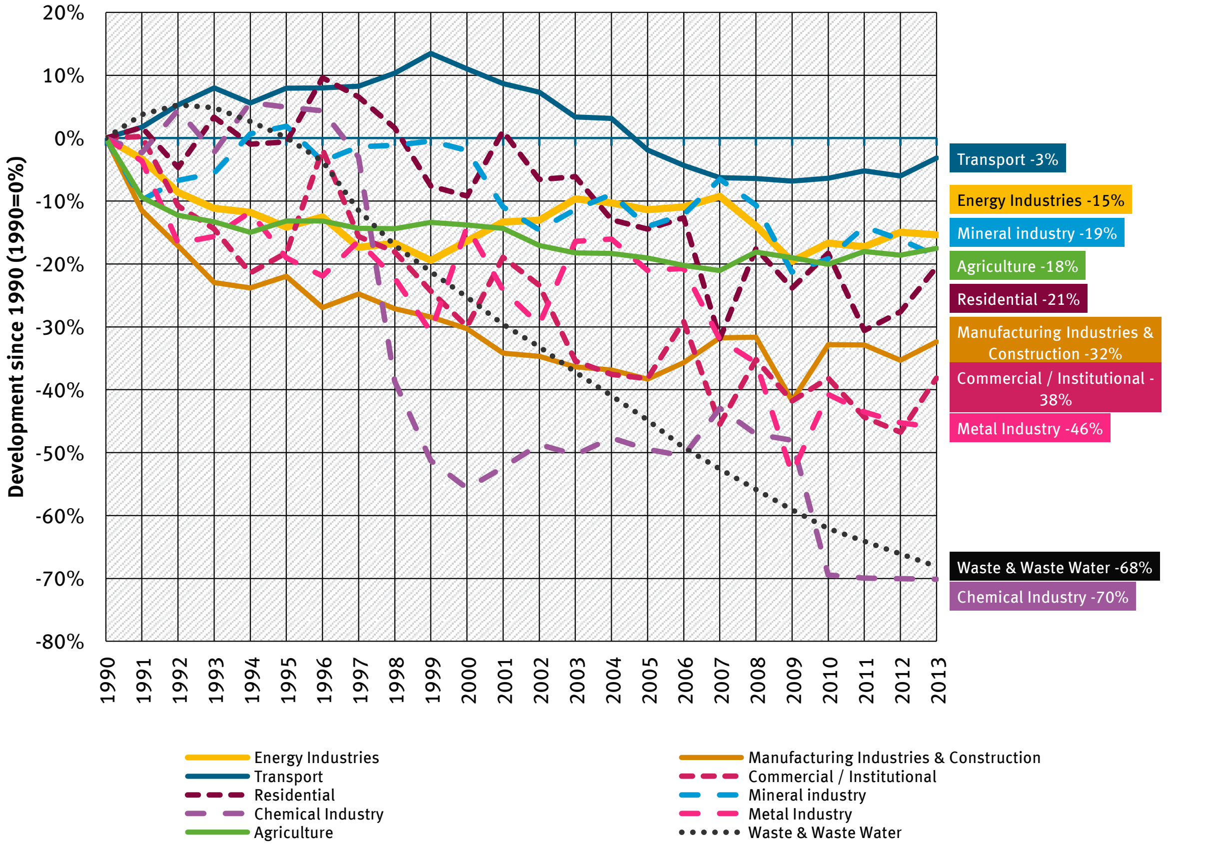


Figure 3: Relative development of greenhouse-gas emissions since 1990, by categories[12,13]

0.3.2 KP-LULUCF activities (ES.3.2)

Germany reports under KP-LULUCF Article 3 (3). It also reports in the areas of forest management, cropland management and grazingland management with regard to the selected additional activities pursuant to Article 3 (4) Kyoto Protocol. It reports emissions of the greenhouse gases carbon dioxide, methane and nitrous oxide.

Under Article 3.3, it is reporting removals of -3,297.51 Gg CO_2 equivalent for the year 2013. The removals consist of -6,061.46 Gg CO_2 equivalent of removals via afforestation and reforestation and 2,763.95 Gg CO_2 equivalent of emissions from deforestation. In the category deforestation, it is reporting CO_2 emissions of 2,688.35 Gg CO_2, CH_4 emissions of 23.60 Gg CO_2 equivalent and N_2O emissions of 51.99 Gg CO_2 equivalent .

Under Article 3.4, it is reporting removals of 17,537.84 Gg CO_2 equivalent in the year 2013.

[12] CO_2 emissions from, and removals in, soils are reported under land-use changes and forestry.
[13] The reference value consists of the emissions in 1990 (=100%), and not of base-year emissions.

1 INTRODUCTION

1.1 Background information regarding greenhouse-gas inventories and climate change, and supplementary information as required pursuant to Article 7 (1) of the Kyoto Protocol

1.1.1 Background information about climate change

Climate change consists of changes in average weather conditions, and in extreme events, over an extended period of time; it can occur in a particular area or be global.

Climate change may be attributable to the following causes:

- Changes in so-called "geo-astrophysical parameters" such as the solar constant, elements of the earth's orbit, etc.
- Changes in the earth's surface
- Changes in the energy balance in the "earth's surface and atmosphere" system
- Changes in the substance balance in the atmosphere (such as changes in the concentration of greenhouse gases).

Greenhouse gases, among which are carbon dioxide, nitrous oxide (laughing gas), methane, ozone and other gases (especially water vapour, the most important natural greenhouse gas), have a particular property: They allow the energy-rich radiation falling onto the earth from the sun (primarily in the visible, short-wave range) to pass almost unhindered, yet partially absorb the long-wave radiation emitted by the heated earth. This places them in an energetically excited state for a brief time, after which they return to their original basic state whilst emitting infrared radiation. Heat radiation occurs equally in all spatial directions – in other words, a substantial portion of this is returned to the earth's surface (”*thermal back radiation*”). So that this additional quantity of energy may nevertheless be irradiated (this must occur due to the dynamic, energetic equilibrium, at whose centre are the earth and the atmosphere), the earth must have a correspondingly higher temperature. This is a simplified description of the greenhouse effect.

Without the greenhouse gases occurring naturally, life on our planet would not be possible. Instead of having an average global temperature of approximately 15°C, the earth would have an average temperature of approximately –18°C. In other words, the natural greenhouse effect protects our life on earth.

Since the beginning of the industrial era, mankind has brought about marked changes in the atmosphere's substance cycles, however. These changes have been caused by humans' energy-intensive lifestyles and related emissions of greenhouse gases. Between 1750 and 2013, the worldwide concentration of carbon dioxide (CO_2) increased by about 43 % (Global Carbon Project, 2014), while that of methane (CH_4) increased by a factor of about 2.5 and that of nitrous oxide (N_2O) increased by about 20 % (BLASING, T.J., 2014). Furthermore, a number of brand-new substances – i.e. substances that for all intents and purposes do not occur in nature and are produced almost exclusively by humans – such as chlorofluorocarbons (CFCs), halons, perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3) have entered the atmosphere. In spite of being "trace gases", greenhouse gases have considerable impacts. Their increasing concentrations have led to the anthropogenic (human-caused) greenhouse effect, which supplements the natural greenhouse effect.

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (2007) (AR5, 2013) has clearly confirmed that the earth's climate is currently changing. A wide range of changes have occurred throughout the entire climate system since the middle of the last century. The temperature of the lower atmosphere is rising, the oceans are warming, glaciers are melting, permafrost soils are thawing, icecaps are losing mass and sea levels are continuing to rise.

Extensive observations, expanded models and profound insights into the pertinent interrelationships indicate, with great reliability, that human activities are the main cause of the climate change currently taking place.

Significant examples of observed climate changes include the following:

- From 1880 to 2012, the global mean temperature near the ground rose by 0.85 °C. Each of the past three decades has been warmer than all previous decades since 1850. In the northern hemisphere, the last 30-year period (from 1983 to 2012) was the warmest such period in the past 1400 years.
- Eight of the last ten years have been among the ten warmest that have occurred since 1864, when scientific recording of temperatures began.
- In the period 1971 to 2010, the oceans have stored more than 90 % of the additional energy fed into the climate system. From 1971 to 2010, the temperature in the oceans' upper 75 meters rose by an average of 0.11°C per decade. The water in the deep ocean, below 3000 m, has also warmed.
- Glaciers around the world have continued to retreat, apart from just a few exceptions, and the earth's polar icecaps have lost mass.
- As a result of continuing melting of glaciers and icecaps, and of warming-related ocean-water expansion, the global mean sea level rose by about 19 cm from 1901 to 2010.

The climate change will have extensive impacts on ecological and societal systems, with potentially serious consequences.

If dangerous impacts of climate change are to be prevented, global warming must be constrained to no more than 2 °C in comparison to pre-industrial levels. Of that increase, 0.85°C have already taken place. Successful limiting of warming to less than 2 °C can be expected only in a scenario with highly ambitious climate policies.

The latest research findings indicate that greenhouse-gas emissions must reach their final maximum no later than 2020 and that a trend reversal must then begin taking place. In subsequent years, global emissions then urgently need to be reduced by at least 50 % by the year 2050, with respect to the emission level of the year 2000 .

1.1.2 Background information about greenhouse-gas inventories

The world's nations were quick to recognize that the expected temperature changes would pose threats to ecosystems and to human civilisation, because the changes would take place relatively quickly, and existing systems would not be able to adapt to the new climate conditions without suffering damage.

The Framework Convention on Climate Change was adopted in 1992, in Rio de Janeiro, by nearly all nations of the world. Since 1994, the countries listed in Annex I of the Framework Convention on Climate are required to submit annual inventories of greenhouse gases, as of 15 April of each year, to the Secretariat of the Framework Convention. Such inventories must include data on emissions and sinks for the base year (1990 for CO_2, N_2O, CH_4; 1995 for HFCs, PFCs, SF_6 and NF_3) and for all years until two years prior to the year of the relevant report.

At the third Conference of the Parties, held in Kyoto, legally binding obligations on emissions limitations and reductions were defined, for the first time, for industrialised countries. Under the Kyoto Protocol, industrialised nations were required to reduce their emissions of the six greenhouse gases carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) by an average of 5.2 percent in the period 2008 through 2012[14].

In the second commitment period of the Kyoto Protocol, the list of relevant gases was expanded to include nitrogen trifluoride (NF_3) and six hydrofluorocarbons (HFC-152, HFC-161, HFC-236cb, HFC-236ea, HFC-245fa, HFC-365mfc) and two fully fluorinated hydrocarbons (c-C_3F_6, $C_{10}F_{18}$). For the first commitment period, the European Union adopted an obligation to reduce emissions by 8 %, with respect to the base year. For the second commitment period in the framework of the Kyoto Protocol, the European Union has adopted an obligation to reduce its GHG emissions by 20 %, with respect to the base year, by 2020. Via the European Effort Sharing Decision[15], that obligation has been divided among the 28 Member States and the European Union. While emissions reductions in those areas of inventories that are subject to emissions trading are implemented at the European level, the Member States are responsible at the national level for emissions reductions in inventory areas not subject to emissions trading. Germany is obligated to reduce its emissions to 445.9 million tonnes of CO_2-equivalents.

In the second commitment period of the Kyoto Protocol – as in the first – the effectiveness and success of the Kyoto Protocol vis-à-vis reduction of global greenhouse gas emissions depend on two key factors: Whether its Parties abide by the rules of the Protocol and meet their obligations, and whether the emissions data used for controlling compliance are reliable. As such, national reporting and the subsequent international review of emissions inventories play a key role.

1.1.3 Background information relative to supplementary information, as required pursuant to Article 7 (1) of the Kyoto Protocol (KP NIR 1.1.3.)

Pursuant to decision 15/CMP.1 of the 1st COP of the Kyoto Protocol, as of 2010 all of the countries listed in ANNEX I of the UN Framework Convention on Climate Change that are also parties to the Kyoto Protocol must submit annual inventories in order to be able to make use of flexible mechanisms pursuant to Articles 6, 12 and 17 of the Kyoto Protocol.

In 2008 (with the NIR 2008), Germany began early, on a voluntary basis, to fulfill these reporting obligations. In the process, over the past two years it has begun preparing intensively for the binding reporting required pursuant to Art. 7 of the Kyoto Protocol.

The first binding report, that for 2010 (NIR 2010), was reviewed in detail in September 2010 in the framework of an In-Country Review. The remarks made in the 2010 In-Country Review

[14] The average reduction, 5.2 %, was calculated from the emissions limitations and reductions that the various parties to the Kyoto Protocol entered in the Protocol's Annex B.

[15] Decision No 406/2009/EC of the European Parliament and of the Council of 23 April 2009

were implemented in a resubmission of November 2010, in subsequent reports in the period 2011 through 2013 and in the 2014 report.

In submitting its thirteenth National Inventory Report (NIR 2015), Germany also submits its eighth inventory report pursuant to the Kyoto Protocol (now the first such report under the second commitment period) that includes all of the information called for in Art. 7. In addition, along with the 2015 NIR, Germany submits its report, as required pursuant to Decision 2/CMP.8, on calculation of its assigned amount of emissions allowances (Kyoto units).

Information relative to Arts. 3.3 and 3.4 of the Kyoto Protocol (KP-LULUCF) is provided in Chapter 8. Information on accounting of Kyoto units for the second commitment period is provided in Chapter 8. The relevant changes in the National System are described in Chapter 13, and the changes in the National Registers are described in Chapter 12. Information on minimisation of negative influences pursuant to Art. 3 (14) of the Kyoto Protocol is presented in Chapter 15.

1.2 Description of institutionalisation of inventory preparation, including the legal and procedural definitions relative to the planning, preparation and management of the inventory

Decision 24/CP.19 calls on all Annex I states to establish and describe national institutions for preparation of greenhouse-gas inventories. In addition, Article 5.1 of the *Kyoto Protocol* calls on the parties to the Kyoto Protocol to establish National Systems for preparation of GHG inventories. The requirements pertaining to such systems are set forth in the *Guidelines for National Systems* (UNFCCC Decision 19/CMP.1). The National system for Germany fulfills the requirements, as set forth by both decisions and by the European Regulation on a mechanism for monitoring and reporting greenhouse gas emissions in the European Union and its Member States[16]

The National System provides for the preparation of inventories conforming to the principles of transparency, consistency, comparability, completeness and accuracy. Such conformance is achieved through use of the methodological regulations from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, through ongoing quality management and through continuous inventory improvement.

The National System has been institutionalised in a process lasting from 2007 to 2011, and on the basis of a 2007 agreement between state secretaries of the involved ministries. Initially, this occurred via the establishment of a National Co-ordinating Committee and of pertinent in-house regulations for the Federal Environment Agency (UBA). Later, institutionalisation was completed primarily via signing of relevant agreements with other federal institutions, with industrial associations and with individual business enterprises. In 2013 and 2014, the National System was adapted to the requirements applying under the second commitment period of the Kyoto Protocol and expanded (cf. Chapter 12)

The requirements-conformal institutionalisation and function of the National System has been confirmed by all reviews carried out to date in the framework of the first commitment period of the Kyoto Protocol.

[16] Regulation (EU) No 525/2013 of the European Parliament and of the Council of 21 May 2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change

1.2.1 Overview of the institutional, legal and procedural definitions relative to preparation of greenhouse-gas inventories and of supplementary information as required pursuant to Article 7 (1) of the Kyoto Protocol

In Germany, the National System has been institutionalised, in the main, at three levels: at the ministerial level, at the level of the Federal Environment Agency (UBA), and at a level outside of the federal administrative sector.

At the ministerial level, the National System has been established under the leadership of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), via an agreement 5 June 2007 signed by state secretaries of the participating ministries that serves as a pertinent policy paper and is entitled "National Emissions Reporting System" ("Nationales System zur Emissionsberichterstattung"). With the inclusion of the Federal Ministry of Food and Agriculture (BMEL), the Federal Ministry for Economic Affairs and Energy (BMWi), the Federal Ministry of Transport and Digital Infrastructure (BMVI), the Federal Ministry of the Interior (BMI), the Federal Ministry of Finance (BMF) and the Federal Ministry of Defence (BMVg), all key institutions and organisations are now involved in preparing emissions inventories that are in a position to provide high-quality specialised contributions (cf. Chapter 1.2.1.4). The policy paper on emissions reporting defines the relevant responsibilities of the various participating federal ministries, and it mandates that the National System is to be built on the basis of existing data streams. Where the data streams are incomplete, the pertinent gaps are to be closed by the responsible ministries, via suitable activities. In support of the reporting process, the participating ministries established a co-ordinating committee (cf. Chapter 1.2.1.1).

The "National Emissions Reporting System" policy paper also assigns the Federal Environment Agency the task of serving as the Single National Entity for Germany (cf. Chapter 1.2.1.2). At the level of the Federal Environment Agency, the Single National Entity integrates other specialised agencies within the National System and coordinates the contributions of the other institutions and organisations involved in emissions reporting. For co-ordination of pertinent work within the Federal Environment Agency, a working group on emissions inventories was established (cf. Chapter 1.2.1.3). For implementation of the IPCC Good Practice Guidance within the Federal Environment Agency, with regard to quality control and assurance, a Quality System of Emissions was established in 2005, via an in-house directive (cf. Chapter 1.3.3.1.1).

The following Figure 4 provides an overview of the structure of the National System in Germany.

The "National Emissions Reporting System" policy paper of 5 June 2007 is presented in Annex Chapter 22.1.1.

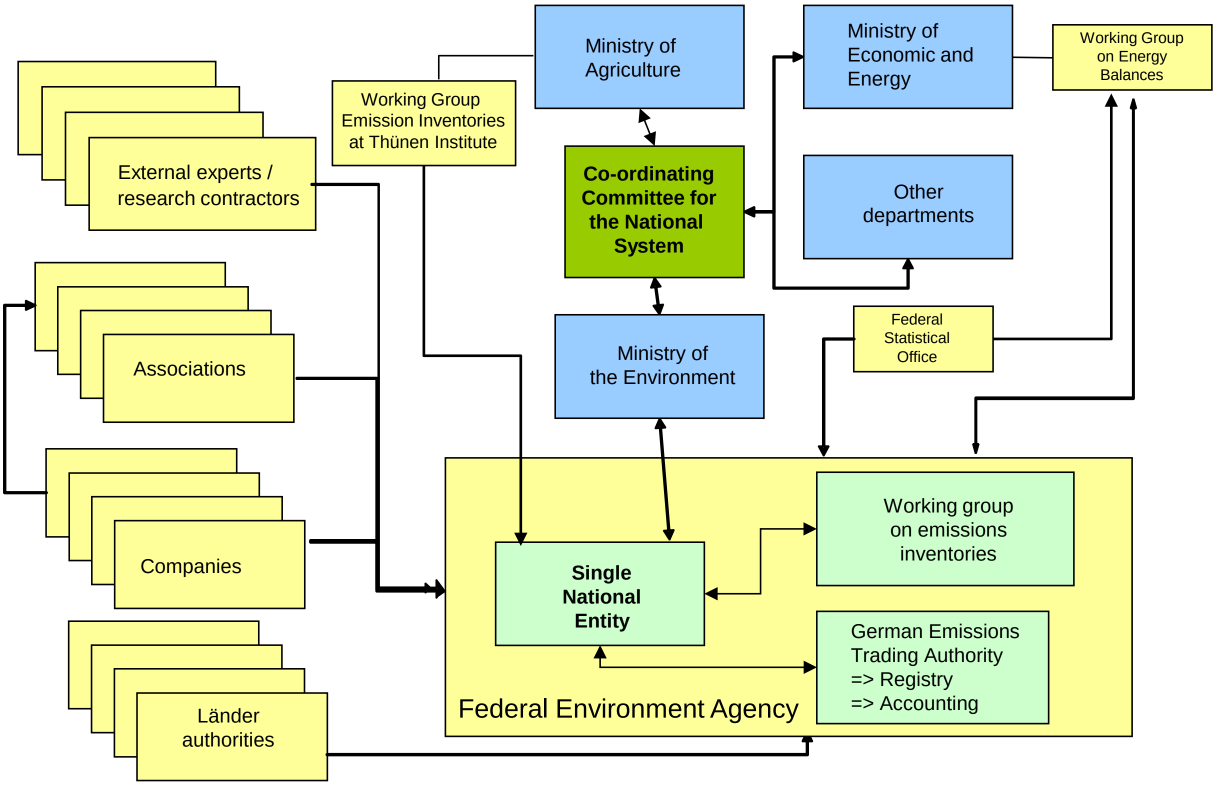


Figure 4: Structure of the National System of Emissions (NaSE)

1.2.1.1 The National Co-ordinating Committee

In its Sec. 2, the state secretaries' resolution of 5 June 2007 provides for the establishment of a National Co-ordinating Committee that is to be headed by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and to include representatives of all federal ministries that participate in emissions reporting.

The National Co-ordinating Committee has the tasks of supporting the emissions-reporting process and clarifying open issues pertaining to the National System. In particular, the Committee carries out consultations with regard to gaps in data streams and settles issues pertaining to assigned responsibilities.

In addition, the National Co-ordinating Committee is responsible for approving inventories and the reports required pursuant to Arts. 5, 7 and 8 of the Kyoto Protocol.

The National Co-ordinating Committee met for the first time on 21 December 2007. It meets at least once per year, at the invitation of the BMUB. Between meetings, the participating federal ministries carry out co-ordination via electronic communication.

In the second commitment period, the National Co-ordinating Committee continues to be an important, established component of the National System.

1.2.1.2 Single National Entity (co-ordination agency) for the National System

Via a policy paper of 05 June 2007, the state secretaries appointed the Federal Environment Agency to carry out tasks of the **Single National Entity** (**national co-ordination agency**) for emissions reporting. The Federal Environment Agency's in-house directive (Hausanordnung) 11/2005 gave section "Emissions Situation" (FG I 2.6) responsibility for carrying out that function.

The Single National Entity's tasks include planning, preparing and archiving of inventories, describing inventories in the inventory reports and carrying out quality control and assurance for all important process steps. The Single National Entity serves as a central point of contact, and it co-ordinates and informs all participants in the National System. During the period 2003 to 2007, the Single National Entity has given priority to developing new data sources. Since 2008, its focus has been especially on a) improving existing data sources and safeguarding their availability for the long term, and b) maintaining the **institutionalisation of the National System**. Furthermore, institutions that need to be integrated within the *National System* have been identified and are now being successively integrated (cf. Chapter 1.2.1.4). In 2014 its work focused especially on implementation of provisions under the second commitment periodof the Kyoto Protocol, and of the Revised UNFCCC Reporting Guidelines, in reporting and in the National System. Other important work has had to do with implementing the Quality System for Emissions Inventories (cf. Chapter 1.2.2).

The Single National Entity has developed two key **instruments** for carrying out those tasks:

The Federal Environment Agency's *Central System on Emissions* (CSE) database is the national, central database for emissions calculation and reporting. It is used for central storage of all information required for emissions calculation (methods, activity data, emission factors). The CSE is the main instrument for documentation and quality assurance at the data level.

Both within and outside of the Federal Environment Agency, the Quality System for Emissions Inventories (QSE) provides the necessary framework for good inventory practice and for routine quality assurance. Established within the Federal Environment Agency in 2005 via in-house directive 11/2005, it comprises the processes necessary for continually improving the quality of greenhouse-gas-emissions inventories. The framework it provides includes defined responsibilities and quality objectives relative to methods selection, data collection, calculation of emissions and relevant uncertainties and recording of completed quality checks and their results (confirmation that objectives were reached, or, where objectives were not reached, listing of the measures planned for future improvement). Ongoing quality improvement in the framework of the QSE is supported by a database that serves as the repository for all tabular documents emerging from the national QC/QA process (QC/QA plan, checklists, lists of responsibilities, etc.).

The quality control procedures have been developed with the help of external experts, taking special account of the Federal Environment Agency's work structures, general guidelines for quality assurance and the *IPCC Good Practice Guidance*. For the second commitment period, the quality control procedures have been brought into line with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Since 2008, the QSE has been expanded to cover the entire National System. This has occurred via integration of additional authorities, institutions and inventory experts in the quality-management process – via specification of minimum requirements for data documentation, QC/QA and archiving. In addition, the procedure is designed to enable other organisations to develop their own internal quality assurance systems on the basis of their existing structures. The QSE is described in detail in Chapter 1.2.2.

The manner in which these instruments interact in the framework of inventory preparation is shown in Figure 5.

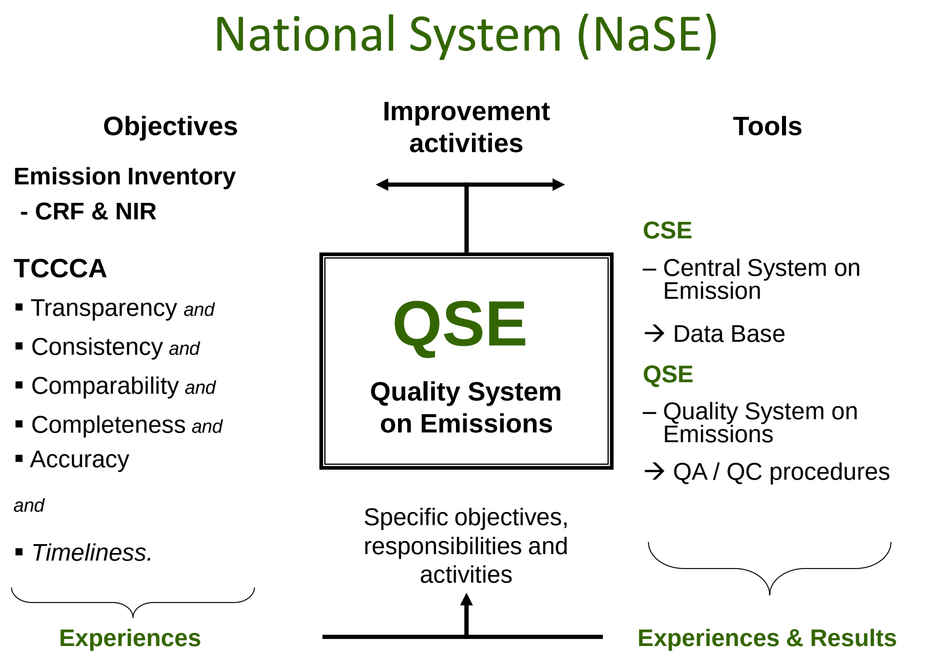


Figure 5: NaSE – Objectives and instruments

1.2.1.3 Working Group on Emissions Inventories, in the Federal Environment Agency

In its inventory work, and especially in work relative to emission factors, the Single National Entity receives significant support from other working units of the Federal Environment Agency. In addition, associations, companies and other independent organisations are integrated within the National System, for purposes of data provision, primarily via the Federal Environment Agency's specialised units that are responsible for the specific issues involved in each case.

In 2003, a *Working Group on Emissions Inventories* was set up to co-ordinate relevant work within the Federal Environment Agency; it liaises with all of the agency's employees who are involved in inventory preparation.

The Single National Entity convenes meetings of the working group at least once a year. In addition, relevant members of the working group meet as necessary to discuss specific issues and to make any necessary in-house arrangements.

Necessary information is provided via the working group's events and through an intranet site, of the Single National Entity, devoted to emissions reporting.

To inform all of the Federal Environment Agency staff who participate in inventory preparation about any relevant changes, the Single National Entity also issues a monthly e-mail newsletter regarding the CSE database and a quarterly e-mail newsletter on the National System.

1.2.1.4 Co-operation by the Single National Entity with other federal institutions and with non-governmental organisations, in the framework of the National System

Via the "National Emissions Reporting System" policy paper of 05 June 2007, the involved ministries defined their responsibilities, relative to the various relevant source and sink categories, for the first commitment period of the Kyoto Protocol.

Furthermore, the relevant resolution sets forth that involved federal ministries are to undertake suitable activities to close data gaps that fall within their areas of responsibility. As necessary, data gaps are to be closed via provision of pertinent data, or via relevant calculations. In some cases, required data may be provided by reliable third parties.

The relevant arrangements are remaining in place during the second commitment period.

For some of the data streams moving to the Single National Entity from other federal institutions, special agreements have been concluded between a) the relevant institution in the case in question and b) the Single National Entity.

With regard to **data provision by the *Federal Statistical Office***, relative to emissions reporting, a legal arrangement was made in 2009, in the framework of the 3rd SME Relief Act (Mittelstandsentlastungsgesetz 3; MEG 3), that enables provision of data, from confidential energy, environmental and production statistics, for purposes of emissions reporting. On that basis, on 13 January 2010 an administrative agreement between the Federal Environment Agency and the *Federal Statistical Office* came into force that specifies data deliveries for emissions-reporting purposes. The agreement provides for annual reviews of the Federal Environment Agency's data requirements. In addition, a process of close direct exchanges between the Single National Entity and the Federal Statistical Office, regarding issues of emissions reporting, has been institutionalised.

The "National Emissions Reporting System" policy paper assigns responsibility for the areas of agriculture and LULUCF to the Federal Ministry of Food and Agriculture (BMEL). The BMEL has commissioned its subordinate departments to carry out the tasks necessary for emissions reporting. That commissioning took place via a directive of 29 July 2007 to the (then) Federal Agricultural Research Centre (FAL). As a result of a restructuring of the FAL as of 1 July 2008, the tasks are now carried out by the **Thünen Institute (TI)**. The relevant work includes all tasks in the agriculture and forestry sectors that are necessary for the preparation of the annual emissions inventories, including the writing of the relevant reports. The TI sends the pertinent data and report to the Single National Entity. With a concept that names and specifies all pertinent processes and actors, and the actors' roles, the BMEL and TI have codified the procedures for preparation of emissions and carbon inventories for source and sink categories 4 and 5 (agriculture and forestry), including a quality assurance concept for KP-LULUCF (Art. 3.3. and 3.4 KP).

In addition, on 13 February 2008, the TI concluded an agreement with the Federal Statistical Office on provision of emissions data on the basis of agricultural statistics. A research and development agreement between the TI and the *Association for Technology and Structures in Agriculture* (KTBL) has been in place since 7 July 2009. That agreement specifies the necessary supporting work for emissions reporting.

Furthermore, a working group on emissions reporting has been established within the TI, to serve as liaison to the Single National Entity within the Federal Environment Agency. That working group also has responsibility for planning and QC/QA for categories CRF 4 and CRF 5.

Responsibility for co-ordination of the Working Group on Emissions Reporting lies with the TI's Institute of Climate-Smart Agriculture (AK). Responsibility for reporting on agriculture and LULUC lies with the same institute, while responsibility for reporting on forests pursuant to the Convention and Kyoto Protocol Arts. 3.3 and 3.4 lies with the TI's Institute of Forest Ecosystems. As of the second commitment period of the Kyoto Protocol, the Thünen Institute of Wood Research (TI-HF) has responsibility for reporting on emissions from harvested wood products (HWP).

The working group on emissions reporting at the TI is integrated within the National System via direct (inter-departmental) participation within the Single National Entity's communications structures. The working group at the TI is also part of the working group ist on emissions inventories (Arbeitskreis Emissionsinventare – AKEI) within the Federal Environment Agency, and it is fully integrated within the Single National Entity's Quality System for Emission Inventories (QSE).

At least twice per year, additional co-ordinating meetings take place between the working group at the TI and the Single National Entity, for purposes of co-ordination and information provision – for example, with regard to inventory improvements and research projects.

Involvement of economic associations, companies and other independent organisations is achieved primarily via those departments of Federal Environment Agency divisions I and III that are responsible for pertinent concrete issues. The *Single National Entity* supports the departments in discussion of reporting requirements and in determination of requirements for data-sharing by associations. The data flows are continually reviewed by the Single National Entity and, where necessary, are safeguarded by suitable agreements between the Single National Entity and associations / business enterprises.

The Working Group on Energy Balances (AGEB) is contractually obligated, via the Federal Ministry for Economic Affairs and Energy (BMWi), to provide Energy Balances. Use of a co-ordinated schedule ensures that a provisional Energy Balance for the last reported year is prepared on time, and is transmitted to the Federal Environment Agency, by 31 July of each year, for purposes of inventory preparation. An effort is made to transmit the final Energy Balance by 28 February of year x+2.

In 2008, a sample agreement was prepared for inclusion of non-governmental agencies within the National System. That agreement is used to involve stakeholders, under binding terms, within preparation of inventories. The sample agreement is adapted to the various data suppliers' own requirements and needs as is necessary. In July 2009, the Federal Ministry for Economic Affairs and Energy (BMWi) and the Federal Environment Agency concluded an agreement, with the German Chemical Industry Association (VCI) and German producers, on data provision in the categories Ammonia (2.B.1) and Nitric acid (2.B.2). In early summer 2014, that agreement was adapted to the requirements applying under the Revised UNFCCC Reporting Guidelines. In addition, in 2009 agreements on data provision were reached with producers of adipic acid (2.B.3) located in Germany. Furthermore, an association agreement was concluded with the VDD industry association for bitumen paper and bitumen roof sheeting relative to the category Bitumen for roof sheeting (2.A.5). Since 2009, data for the aforementioned categories for emissions reporting have been provided on the basis of these agreements. . In June 2011, the Single National Entity, acting with the support of the responsible ministry, the Federal Ministry for Economic Affairs and Energy (BMWi), entered into a cooperation agreement with the Wirtschaftsvereinigung Stahl German steel industry association. That agreement had become necessary because the Federal Statistical Office had discontinued its data collection and publication activities for Fachserie 4 Reihe 8.1 (iron and steel statistics) as of 31 December 2009, due to the expiration of the pertinent legal basis (Raw materials act; Rohstoffstatistikgesetz). That move had considerably reduced the availability of the bases for calculations in that area, and it created a significant gap in the pertinent data streams. The new cooperation agreement closed that gap. The agreement assures data provision by both member companies of the assocation and by non-member companies.

These agreements provide a reliable long-term framework for data provision, and they have had the effect of considerably improving data quality in the relevant categories.

A relevant voluntary commitment of semiconductor manufacturers with production sites in Germany, a commitment that served as the basis for data provision for category 2.F.6, expired on 31 December 2010. In August 2012, the Single National Entity acted to close the resulting potential data gap by entering into a cooperation agreement, with the Electronic Components and Systems (ECS) division of the German Electrical and Electronic Manufacturers' Association (ZVEI), that is designed to assure long-term provision of data to the Federal Environment Agency for category 2.F.6.

1.2.1.5 Binding schedule in the framework of the National System

The binding schedule for preparation of emissions inventories and of the NIR is announced to all relevant internal and external stakeholders via the Federal Environment Agency's intranet site and via publication within the NIR itself:

15 May	The Federal Environment Agency's national co-ordinating agency (Single National Entity) requests responsible experts to submit data and report texts
31 July	Delivery of energy data of the Working Group on Energy Balances (AGEB), of statistical data of the Federal Statistical Office and of data provided under agreements with associations and companies, where such data serve as the basis for further calculations
by 1 September	Deliveries of ready-to-use inventory data from the Federal Environment Agency and from external institutions of the NaSE
as of 2 September	Validation / discussion of deliveries by responsible experts and quality managers, taking account of review results
by 1 October	Preparation of CRF time series and of national trend tables; final editing by the Single National Entity within the Federal Environment Agency
8 November	In-house consultations at the Federal Environment Agency
as of 15 November	Final quality assurance by the QSE/CSE/NIR co-ordinator
25 November	Report of the Single National Entity to the BMUB, for commencement of inter-ministerial co-ordination relative to the CRF data and the National Inventory Report
20 December	Approval via departmental co-ordination (initiated by the BMUB)
2 January	Final editing by the Federal Environment Agency's national co-ordinating agency (Single National Entity)

15 January	Report (CRF and certain parts of the NIR) goes to the European Commission (in the framework of the CO_2 Monitoring Mechanism) and to the European Environment Agency
15 March	Report (corrected CRF and complete NIR) goes to the European Commission (in the framework of the CO_2 Monitoring Mechanism) and to the European Environment Agency
15 April	Report goes to the FCCC Secretariat
May	Initial check by the FCCC Secretariat
June	Synthesis and assessment report I (by the UN FCCC Secretariat)
August	Synthesis and assessment report II (country-specific; by the UN FCCC Secretariat)
September - October	Inventory review by the UN FCCC Secretariat

1.2.2 Overview of inventory planning

Inventory preparation draws on the expertise of *research institutions*, via execution of research projects in the UFOPLAN (environmental research plan) framework. This takes place via consideration of specific questions and via overarching projects. In each of the UFOPLANs for the 2002-2009 period, the Single National Entity had a global project on *updating emissions-calculation methods*, a framework for initiating measures for continuous inventory improvement. In 2010 and 2011, measures for continuous inventory improvement were financed completely via the budget title for expert services. The Federal Environment Agency promised to provide the Single National Entity with funding, from the budget title for expert services (Title 526 02, Chapter 1605), for short-term contracting for purposes of inventory improvement under the responsibility of the Agency. The funding, provided as of 2005, in the interest of emissions reporting, comes in addition to the research funding available from the UFOPLAN. Since 2012, the Single National Entity has again been able to finance research in the framework of emissions reporting from the UFOPLAN. In addition, the budget title for expert services remains available for such financing.

1.2.3 Overview of inventory preparation and management, including overview of supplementary information as required pursuant to Article 7 (1) of the Kyoto Protocol

The emissions-reporting process is a regular, annual process. Since it is a decentralised process, carried out by a range of different persons, it can differ for different parts of the inventory. Prior to the introduction of the QSE (in 2005), this process was intensively studied and analysed. As a result of that work, within the overall emissions-reporting process, the QSE differentiates the following main processes, which are described in detail in Chapter 1.3.2:

- Definition of the bases for calculation,
- Data collection,
- Data processing and emissions calculation, and
- Report preparation.

These main processes are broken down into sub-processes (cf. Figure 6).

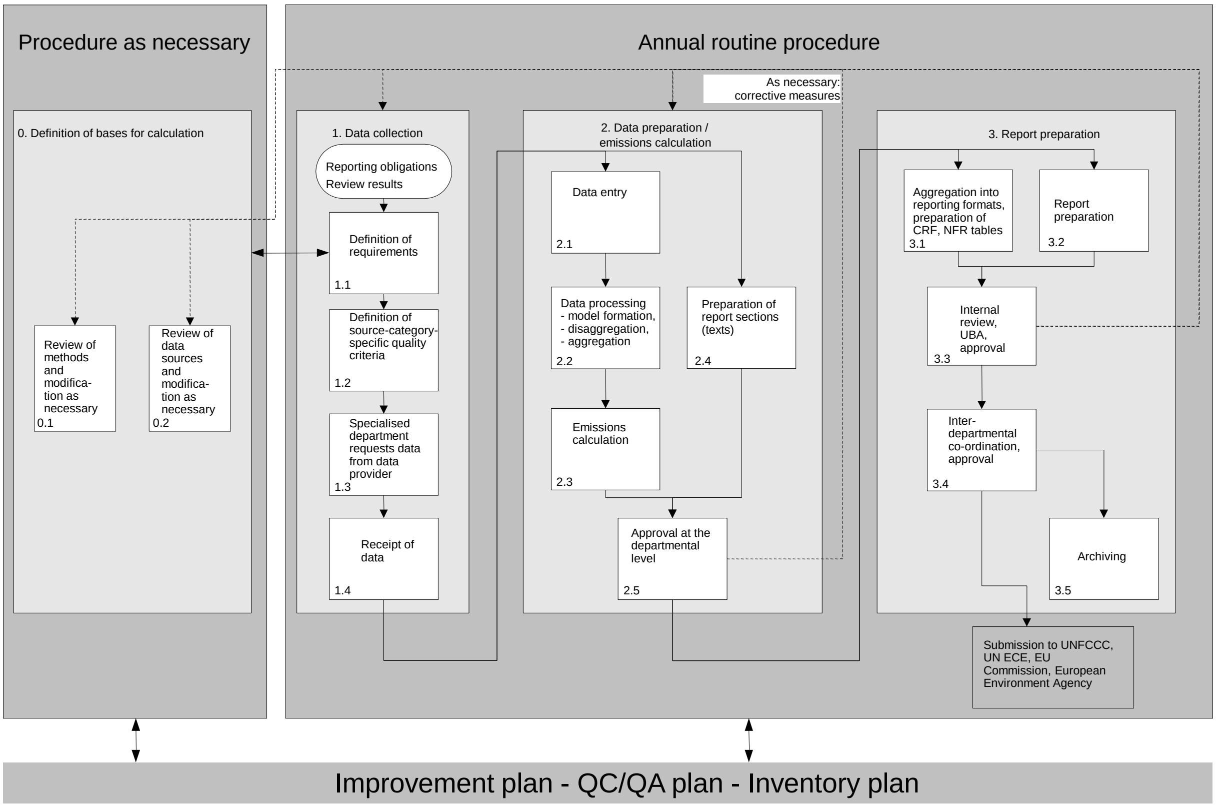


Figure 6: Overview of the emissions-reporting process

Experience has shown that workflow in the inventory planning and preparation process can affect inventory quality, i.e. that the order in which relevant steps are taken is important. That is one of the reasons why the inventory-preparation process is closely tied to quality assurance and control measures. Suitable QC/QA measures have thus been assigned to each sub-process, to ensure that quality assurance not only safeguards the quality of inventory data in its final form, but also safeguards such quality on the pathways leading to that final form. This, in turn, makes it possible to carry out periodical internal evaluations of the inventory-preparation process pursuant to paragraph 15 (d) of the *Guidelines for National Systems*.

The process, including QC/QA measures, fulfills the requirements of paragraphs 14 (a) to (g), with regard to inventory preparation, of the *Guidelines for National Systems*.

The workflow for inventory preparation is described in detail in Chapter 1.3.

The reporting processes address all requirements pursuant to Article 7 of the Kyoto Protocol.

1.3 Inventory preparation

As the overview in Chapter 1.2.3 shows, inventory preparation functions in accordance with a regular, annual scheme. The processes for preparation of greenhouse-gas inventories, KP-LULUCF inventories and National Inventory Reports, and for execution of quality control and quality assurance measures, are very closely linked.

At the same time, the upstream processes for inventory preparation (cf. Chapter 1.3.1.1), including definition of bases for calculation (cf. Chapter 1.3.2.1), and data collection, processing and storage (cf. Chapter 1.3.2), remain distinct from those for quality control and quality assurance (cf. Chapter 1.3.3).

1.3.1 Greenhouse-gas and KP-LULUCF inventories

The upstream processes of inventory preparation and definition of the bases for calculation are identical for greenhouse-gas inventories and for KP-LULUCF inventories.

1.3.1.1 Preliminary/upstream processes

Apart from the sub-processes for emissions reporting, as outlined in Figure 6, certain upstream (preliminary) processes are carried out – in each case, between a pair of emissions-reporting cycles.

The following sub-processes are considered preliminary/upstream processes:

- Continuous review and assurance of data streams from data suppliers to the Federal Environment Agency, via improvement of institutionalisation of the National System;
- Implementation of improvements in inventory planning and inventory preparation;
- Identification of key categories (using Method 1 pursuant to Chapter 4.3.1, Vol. 1 of the IPCC GL 2006);
- Calculation and aggregation of uncertainties relative to emissions, using Monte Carlo simulation (pursuant to Tier 1 or Tier 2, in keeping with the *IPCC Good Practice Guidance*);
- Expanded identification of key categories, via Monte Carlo simulation (using Method 2 pursuant to Chapter 4.3.2, Vol. 1 of the IPCC GL 2006);

1.3.1.1.1 Improvement of the National System

The National System builds on existing data streams, and it provides for suitable measures to assure long-term data provision where such assurance is lacking (cf. Chapter 1.2.1.2). Consequently, data streams continually have to be reviewed between pairs of reporting cycles.

Where voluntary commitments expire, discussions have to be carried out with the relevant data suppliers in order to secure the commitments' renewal or their conversion into cooperation agreements. Where continued data provision is not assured, relevant commitments or co-operation agreements have to be obtained. In cases of any doubt, relevant legal provisions relative to data provision have to be reviewed and implemented.

Existing agreements have to be adapted as necessary to new circumstances and reporting requirements (for example, to changes in reporting procedures). Such efforts help assure the consistent high quality of the National System and the inventory preparation process.

Changes and improvements in the National System, during the current reporting cycle, are described in Chapter 13.

1.3.1.1.2 Implementation of improvements in inventory planning and inventory preparation

Paragraphs 13 and 15(d) of the Guidelines for National Systems (Decision 19/CMP.1) obligate all Annex I countries to strive for continual improvement of inventories and inventory planning.

Wherever possible, the required improvements identified in quality control and quality assurance, and the results of reviews, are implemented between reporting cycles.

A detailed description of the quality control and quality assurance procedures is provided in Chapter 1.6. The improvements achieved for the present report are described in the relevant category chapters.

1.3.1.1.3 Determination of key categories (pursuant to Tier 1)

In order to be able to focus the many and detailed activities and capacities required for inventory preparation and improvement on the principal categories of the inventory, the IPCC has introduced the definition of a "key category". Key categories are source/sink categories that play an especially prominent role in the national inventory because their emissions/removals have a significant influence on the total emissions of direct greenhouse gases – because of their absolute quantities, because of their contribution to the emissions trend over time, because of their uncertainties, or because they have been assessed by an expert as an important category.

The Single National Entity identifies key categories once per year, prior to the emissions-reporting process. Whereas in the reporting framework results are reported for year x, they cannot be taken specifically into account until inventory preparation for the year x+1. A category's designation as a key category helps decide what calculation method (Tier approach) must be used for the category and, as a result, how detailed emissions modelling for the category must be. In addition, the key-category selection process is used to identify any categories to which priority must be given in inventory improvement.

The *IPCC Good Practice Guidance* (2000) specifies the methods to be applied in identifying key categories. These methods identify the relevant key categories with the help of analysis of the inventory for one year with regard to emissions levels for individual categories (Tier 1 level assessment), time-series analysis of inventory data (Tier 1 trend assessment) and detailed analysis of inventory data with error evaluation (Tier 2 level and trend assessment with consideration of uncertainties).

The key categories have been defined by applying the two Approach 1 procedures, Level (for the base year and for the last year reported) and Trend (for the last year reported, as compared to the base year), to German greenhouse-gas emissions. In keeping with IPCC provisions, analyses have taken account of both emissions from sources and removals of greenhouse gases in sinks.

1.3.1.1.4 Calculation and aggregation of uncertainties relative to emissions

Uncertainties are a basic component of emissions inventories; an emissions inventory's uncertainties are determined in order to quantitatively assess the inventory's accuracy. While uncertainties are determined in connection with data gathering, and thus are part of the "data collection" section of the emissions-reporting process, they can be aggregated only after an inventory – or the pertinent emissions-reporting cycle – has been completed.

In calculation and aggregation of uncertainties, uncertainties for activity data and emission factors, which are normally estimated by experts at the lowest category level of the CSE, are converted into uncertainties for emissions and then aggregated. Uncertainties pursuant to Tier 1 are aggregated once per year, at the end of the report-preparation cycle for the current report year. Every three years, uncertainties are additionally determined pursuant to the Tier 2 method.

In the current NIR, Germany reports uncertainties that have been calculated pursuant to the Tier 1 method. For uncertainties determination, the individual uncertainties have been estimated, wherever possible to date, by data-supplying experts of the relevant Federal Environment Agency specialised sections and by external institutions.

1.3.1.1.5 Expanded determination of key categories

Aggregated uncertainties serve as a basis for expanded identification of key categories (Tier 2 key-categories determination).

1.3.2 Data collection, processing and storage, including data for KP-LULUCF inventories

1.3.2.1 Definition of bases for calculation

Selection and review of, and (where necessary) changes in, the calculation methods used to determine emissions affect the entire emissions-reporting process. For this reason, the main process "determination of the bases for calculation" must begin with review of the suitability of the methods to be used. The *2006 IPCC Guidelines* specify, via use of decision trees, what methods are to be used for the various categories. In each case, such methods selection depends on whether the group in question is a key category or not. Any use of different – country-specific – methods, instead of the prescribed methods, must be justified in the NIR. In each case, an outline of why the method in question is of equivalent or higher value is to be provided, along with clear documentation.

Another factor that is critical to the success of the overall process is **selection and review of, and (where necessary) changes in, data sources**, since the quality of results of all downstream processes (data preparation, calculation, reporting) cannot be better than that of the primary data used. Data sources may be oriented to the activity data, emission factors or emissions for/of a specific category. In many cases, the data sources used have been relied on for a number of years. It can become necessary to select new data sources – for example, as a result of required changes in methods, of the elimination of an existing data source, of a need for additional data or of findings from quality checks of previously used data sources.

The suitability of a given data source depends on various criteria. These include:

- Long-term availability,
- Institutionalisation of data provision,
- Good documentation,
- Execution of quality assurance and control measures, by the persons/organisations providing data,
- Identification of uncertainties,
- Representative nature of the data in question, and
- Completeness of the expected data.

In each case, it is vital that the reasons for choosing a particular data source be documented and, where the data source has significant deficits, that suitable measures for improving the data be planned.

Providers of data must always be given requirements relative to quality control, quality assurance and documentation; where research projects are commissioned, this requirement is particularly relevant, since the Federal Environment Agency, as the customer for such services, must be able to influence such projects.

1.3.2.2 Data collection

Data collection and documentation take place under the responsibility of the relevant experts. One way of collecting data is to evaluate official statistics, association statistics, studies, periodicals and third-party research projects. Other ways of obtaining data include carrying out own research projects, applying personally available information and exchanging data via relevant Federal/Länder channels. Often, work results obtained by other means are also reused for the purposes of emissions reporting.

Data collection comprises the following steps:

- Definition of requirements,
- Determination of the category-specific quality criteria for the data,
- Requesting of data from data providers (carried out by the relevant experts' group), and
- Receipt of data.

In each case, the National Single Entity (national co-ordinating agency) also requests inventory input from the experts responsible for the category in question, via the experts' superiors. A master file, specifying the structure for such input, is provided for NIR preparation. The requirements for later data input are provided by the relevant CSE (ZSE) specifications (direct entry or fill-in of the import format). Reporting requirements (including pertinent QC/QA measures), along with the results of all inventory reviews, the databases for the various specific categories and the current results of key-category identification, are all communicated to the responsible experts via informational events held by the *Federal Environment Agency's Working Group on Emissions Inventories*, via the Federal Environment Agency's intranet and share-point sites for emissions reporting and via an electronic inventory description (cf. Chapter 1.3.3.1.5). On this basis, responsible experts **define requirements** relative to data sources and to calculation methods.

Such requirements influence the upstream process of defining the bases for calculation (review and selection of methods and data sources) – a process which always takes place when requirements have not yet been fulfilled or have changed.

Before any third parties begin with data collection – after the requirements pertaining to data sources and methods have been defined – the **category-specific quality criteria for such third-party data should be defined**, in order to support the QC process on the data level.

When a responsible expert **requests data** from a third party able to supply data, the expert is expected to accompany his or her request with a description of the amount of data expected from the prospective data supplier, of the relevant data-quality requirements and of the relevant data-documentation requirements. Upon **receipt of data**, the data are checked for completeness, compliance with quality criteria and currentness. Data validation is carried out by the relevant expert.

1.3.2.3 Data preparation and emissions calculation

The process of data preparation and emissions calculation comprises the following steps:

- Data entry,
- Data preparation (model formation, disaggregation, aggregation),

- Calculation of emissions,
- Preparation of report sections (texts), and
- Approval by the relevant experts.

Report texts are prepared along with the time series for activity data, emission factors, uncertainties and emissions. As a result, the term "data" is understood in a broad sense. In addition to number data, time series, etc., it also includes contextual information such as the sources for time series, and descriptions of calculation methods, and it also refers to **preparation of report sections** for the NIR and documentation of recalculations.

Large shares of **data entry and processing** (processing of data, and emissions calculation) take place in the CSE. This considerably enhances transparency and consistency, and it opens up the possibility of automating required data-level quality-control measures in the CSE (such as checking of orders of magnitude and of completeness, and specification of checking parameters in CalQlator). In cases that lend themselves to such automation, certain QC measures then do not have to be carried out manually. At the same time, plausibility cross-checks, with simplified assumptions, should be applied to results of calculations with complex models.

After all checks have been carried out, and the relevant parties have been consulted where necessary, the **emissions are calculated** in the CSE by means of an automated procedure, based on the following principle:

activity data * emission factor = emission

If upstream calculation routes are also stored in the CSE, these calculations are initiated first, before the actual calculation of emissions takes place.

In each case, the relevant expert responsible for QC also has responsibility for **issuing expert-level approvals**, for written texts and for calculation results, prior to any further use of such texts and results by the Single National Entity. Such issuance normally takes place in connection with transmission to the Single National Entity, and it is carried out via approval of completed QC/QA checklists.

1.3.2.4 Report preparation

Report preparation includes the following steps:

- Aggregation of emissions data for the national trend tables and reporting formats, preparation of data tables for the NFR, export / import of XML files into the CRF reporter,
- Compilation of submitted report texts to form a report draft (NIR), and editing of the complete NIR,
- Internal review of the draft (national trend tables and NIR) by the Federal Environment Agency, followed by approval as appropriate,
- Handover to the BMUB, for interdepartmental co-ordination, leading to approval by the co-ordinating committee, followed by the final steps of
- Handover to the UNFCCC Secretariat, the EU Commission and the UNECE Secretariat, and
- Archiving.

Following complete preparation of data, report sections and QC/QA checklists by the responsible experts, and transmission of those materials to the Single National Entity, the materials are reviewed by category-specific, specialised contact persons at the Single National Entity, on the basis of a QC checklist. The results of this review are then provided to the relevant responsible experts, to enable these experts to revise their contributions (if necessary, following suitable consultation) accordingly.

Before emissions data can be transferred into the report formats for the Framework Convention on Climate Change (CRF = Common Reporting Format), the Kyoto Protocol and the UN ECE Geneva Convention on Long-range Transboundary Air Pollution (NFR = New Format on Reporting), emissions data from CSE time series (in the data-collection format) **must be aggregated** into the CRF/NFR category **report formats**. This is accomplished via hierarchical allocation within the CSE, a process that, in Annex 3, is described in detail for the various key categories. Where no changes with respect to the previous year have occurred, the aggregations are carried out automatically.

Following calculatory aggregation, activity data and emissions are read, via export in XML-file form, into the CRF reporter, which automatically prepares the IPCC CRF reporting tables. Nonetheless, quality control still has to be carried out to ensure that the emissions inventory and the CRF-Reporter tables agree with respect to relevant values and to the implied emission factors calculated by the CRF Reporter. Furthermore, suitable explanatory remarks have to be provided for any recalculations and notation keys.

Calculation of greenhouse gases in CO_2 equivalents is carried out in keeping with Art. 2 of Decision 24/CP.19 and of Art. 31 of the Revised UNFCCC Reporting Guidelines (FCCC/CP/2013/10/Add. 3), on the basis of the relevant global warming potentials (GWP), as published in the *Fourth Assessment Report*. The GWP, which are oriented to greenhouse gases' impacts within a 100-year time frame, are listed in the following table.

Table 3: Global Warming Potentials (GWP) of greenhouse gases

Greenhouse gas	Chemical formula	IPCC AR4 GWP
Carbon dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	298
Hydrofluorocarbons (HFC)		
HFC-23	CHF_3	14800
HFC-32	CH_2F_2	675
HFC-41	CH_3F	92
HFC-43-10mee	$CF_3CF_2CHFCHFCF_3$	1640
HFC-125	CHF_2CF_3	3500
HFC-134	CHF_2CHF_2	1100
HFC-134a	CH_2FCF_3	1430
HFC-143	CHF_2CH_2F	353
HFC-143a	CF_3CH_3	4470
HFC-152	CH_2FCH_2F	53
HFC-152a	CH_3CHF_2	124
HFC-161	CH_3CH_2F	12
HFC-227ea	CF_3CHFCF_3	3220
HFC-236cb	$CH_2FCF_2CF_3$	1340
HFC-236ea	CHF_2CHFCF_3	1370
HFC-236fa	$CF_3CH_2CF_3$	9810
HFC-245ca	$CHF_2CF_2CH_2F$	693
HFC-245fa	$CHF_2CH_2CF_3$	1030
HFC-365mfc	$CH_3CF_2CH_2CF_3$	794

Greenhouse gas	Chemical formula	IPCC AR4 GWP
Perfluorocarbons (PFC)		
Perfluoromethane	CF_4	7390
Perfluoroethane	C_2F_6	12200
Perfluoropropane	C_3F_8	8830
Perfluorocyclopropanes	$c\text{-}C_3F_6$	17340
Perfluorobutanes	C_4F_{10}	8860
Perfluorocyclobutanes	$c\text{-}C_4F_8$	10300
Perfluoropentanes	C_5F_{12}	9160
Perfluorohexanes	C_6F_{14}	9300
Perfluorodecalin	$C_{10}F_{18}$	7500
Sulphur hexafluoride		
Sulphur hexafluoride	SF_6	22800
Nitrogen trifluoride		
Nitrogen trifluoride	NF_3	17200
Fluorinated ethers		
HFE-125	CHF_2OCF_3	*14900*
HFE-134	CHF_2OCHF_2	*6320*
HFE-143a	CH_3OCF_3	*756*
HFE-227ea	$CF_3CHFOCF_3$	*1540*
HCFE-235da2	$CHF_2OCHClCF_3$	*350*
HFE-236ca12	$CHF_2OCF_2OCHF_2$	*2800*
HFE-236ea2	$CHF_2OCHFCF_3$	*989*
HFE-236fa	$CF_3CH_2OCF_3$	*487*
HFE-245cb2	$CH_3OCF_2CF_3$	*708*
HFE-245fa1	$CHF_2CH_2OCF_3$	*286*
HFE-245fa2	$CHF_2OCH_2CF_3$	*659*
HFE-254cb2	$CH_3OCF_2CHF_2$	*359*
HFE-263fb2	$CF_3CH_2OCH_3$	*11*
HFE-329mcc2	$CHF_2CF_2OCF_2CF_3$	*919*
HFE-338mcf2	$CF_3CH_2OCF_2CF_3$	*552*
HFE-338mmz1	$(CF_3)_2CHOCHF_2$	*380*
HFE-338pcc13	$CHF_2OCF_2CF_2OCHF_2$	*1500*
HFE-347mcc3	$CH_3OCF_2CF_2CF_3$	*575*
HFE-347mcf2	$CHF_2CH_2OCF_2CF_3$	*374*
HFE-347mmy1	$(CF_3)_2CFOCH_3$	*343*
HFE-347pcf2	$CHF_2CF_2OCH_2CF_3$	*580*
HFE-356mec3	$CH_3OCF_2CHFCF_3$	*101*
HFE-356mmz1	$(CF_3)_2CHOCH_3$	*27*
HFE-356pcc3	$CH_3OCF_2CF_2CHF_2$	*110*
HFE-356pcf2	$CHF_2CH_2OCF_2CHF_2$	*265*
HFE-356pcf3	$CHF_2OCH_2CF_2CHF_2$	*502*
HFE-365mcf3	$CF_3CF_2CH_2OCH_3$	*11*
HFE-374pc2	$CHF_2CF_2OCH_2CH_3$	*557*
HFE-449sl	$C_4F_9OCH_3$	*297*
HFE-569sf2	$C_4F_9OC_2H_5$	*59*
HFE-43-10pccc124	$CHF_2OCF_2OC_2F_4OCHF_2$	*1870*
	$CF_3CF_2CH_2OH$	*42*
	$(CF_3)_2CHOH$	*195*
	$-(CF_2)_4CH(OH)-$	*73*
Perfluoropolyethers		
PFPMIE	$CF_3OCF(CF_3)CF_2OCF_2OCF_3$	*10300*

Source: FCCC/CP/2013/10/Add. 3, p.24

At the same time, the report co-ordinator **compiles the checked report texts to produce the draft** of the NIR.

Review and approval, **within the Federal Environment Agency**, of the completed report tables and the NIR, and of the inventory plan to be included in future, are certified via co-signing in the framework of the Federal Environment Agency's **internal co-ordination process**. Then, the materials are **forwarded** to the BMUB, for the second approval phase within the framework of **interdepartmental co-ordination**. In a concluding step, the co-ordinating committee approves the report tables and the NIR for submission to the UNFCCC Secretariat. The ministry arranges for translation of the NIR and for its **submission to the UNFCCC Secretariat**.

The data tables and the pertinent NIR are archived in secure form in the inventory description (cf. also Chapter 1.3.3.1.5). The content of the CSE database used for calculation purposes is also archived.

1.3.3 Procedures for quality assurance and quality control (QA/QC), and detailed review of greenhouse-gas and KP-LULUCF inventories

1.3.3.1 The Quality System for Emissions Inventories

The QSE takes account of provisions of the *2006 IPCC Guidelines (Vol. 1, Chapter 6)*, of national circumstances in Germany and of the internal structures and procedures of the Federal Environment Agency (UBA), the reporting institution. The QSE's procedures are flexible enough to be able to routinely incorporate future changes in requirements. The QSE's scope of application comprises the entire emissions-reporting process.

The QSE covers all participants of the NaSE. Within the Federal Environment Agency, the QSE has been made binding via the agency's in-house directive (UBA-Hausanordnung) 11/2005. Details regarding assurance of the QSE's binding nature for other NaSE participants are provided in Annex 22.1.1.

1.3.3.1.1 Directive 11/2005 of the Federal Environment Agency

In 2005, via its *in-house directive (Hausanordnung) 11/2005*, the Federal Environment Agency established a *Quality System for Emissions Inventories* (QSE), within the Agency. The QSE provides the necessary framework for compliance with good inventory practice and for execution of routine quality assurance. The QSE conforms to the provisions of the *2006 IPCC Guidelines (Vol. 1, Chapter 6)*, and it has been adapted to the national circumstances prevailing in Germany and to the internal structures and procedures of the Federal Environment Agency (UBA), the reporting institution. The in-house directive (Hausanordnung 11/2005) issues binding provisions on relevant competencies within the Agency, lists deadlines for the various inventory-preparation steps and describes the necessary relevant review actions for purposes of quality control / quality assurance.

The directive has fulfilled requirements, pursuant to Paragraph 10 (a) of the *Guidelines for National Systems*, for specification of relevant procedures, and for definition, pursuant to Paragraph 12 (c), of specific responsibilities at the Agency level.

1.3.3.1.2 *Minimum requirements pertaining to a system for quality control and assurance*

The requirements pertaining to the system for quality control and quality assurance (QC/QA system) and to measures for quality control and quality assurance are defined primarily by Chapter 6 of the *2006 IPCC Guidelines (Vol. 1)*.

In 2007, the Federal Environment Agency derived General minimum requirements pertaining to a quality control and quality assurance system for GHG-emissions reporting" ("Allgemeine Mindestanforderungen an die Qualitätskontrolle und Qualitätssicherung bei der Treibhausgasemissionsberichterstattung") from the previously applicable Good Practice Guidance (Chapter 8) (cf. Chapter 22.1.2.1). External National System participants then adopted the minimum requirements after representatives of the participating federal ministries approved them in the framework of the National Co-ordinating Committee for the National System of Emissions Inventories (cf. Annex Chapter 22.1.1).

Further information regarding the Federal Environment Agency's necessary organisational measures for implementing these requirements is provided in the following chapters and in a complementary section in the Annex, 22.1.2.1.11.

1.3.3.1.3 *Start-up organisation for establishing the Quality System for Emissions Inventories*

Within the QSE framework, a concept for a start-up organisation was developed that defines binding responsibilities, for the Federal Environment Agency, for implementation of the necessary QC and QA measures. The defined roles and responsibilities have the purpose of facilitating effective information exchange and directive-conformal execution of QC and QA (cf. Table 4).

Table 4: QSE – Roles and responsibilities

Role	Task	Responsible
Responsible expert at the operational level (FV)	Preparation of parts of the National Inventory Report (NIR) Data collection and data entry in the CSE, and calculation in keeping with the selected//prescribed methods Execution of systematic QC measures in the NIR, CSE and inventory description Execution of verification measures Archiving of all category-specific inventory information (inventory description and decentralised documentation) If necessary (for category-specific QC): Definition of category-specific quality targets and of the criteria for their achievement, in consultation with the QC section representative, the specialised contact person and the QC/QA co-ordinator (QSEK). Review, processing and answering of review results Active participation in review processes. This includes giving presentations, providing explanations and being available for questions (before and during the process, and in any follow-up). Initiating and developing (preparing specifications) R&D projects, and providing specialised support	All category-specific staff appointed by the head (FGL)
QC/QA section representative (QKV)	Execution of systematic measures for assuring the quality of the data and report sections delivered to the Single National Entity Checking and approving data and report sections Ensuring that the necessary inventory work, quality controls, documentation and archiving are carried out Defining responsibilities relative to emissions reporting in specialised fields, and provision of the necessary time resources Providing support for review processes, and participating in them	All responsible heads (Federal Government and the Länder)

Role	Task	Responsible

Specialised contact person (category-specific) in the SNE (FAP)	Category-specific support for responsible experts (FV) and QC/QA section representatives (QKV); support/guidance of FV/QKV in:
	• Implementation of international requirements
	• Supporting work involving data and report texts
	• Quality control / quality assurance
	  ○ Preparation of lacking parts of the National Inventory Report (NIR)
	  ○ Collection of any data lacking in the CSE, entry of such data into the CSE and carrying out of calculations in keeping with the selected/prescribed methods
	  ○ Ensuring that the necessary inventory work, quality controls, documentation and archiving are carried out
	  ○ Execution of systematic QC/QA measures in the NIR, CSE and inventory description
	  ○ Archiving of any lacking category-specific inventory information (inventory description and decentralised documentation)
	Initiating and supporting R&D projects
	Execution of all work using the CRF reporter, and execution of quality control
	Assumption of tasks of unavailable responsible experts (FV) and of positions that have not been filled
	Review, processing and answering (as necessary) of review results
	Support, participation in and execution of (as necessary) FV tasks in connection with review processes
	Execution of overarching work (affecting more than one category)
	If necessary (for category-specific QC): Definition of category-specific quality targets and of the criteria for their achievement, in consultation with the QC section representative, the specialised contact person (FAP) and the QC/QA co-ordinator (QSEK).
		Single National Entity (SNE) staff members appointed to specific categories

Report co-ordinator (NIRK)	Coordination of text contributions Compilation of the NIR, from the various contributions Overarching QC and QA for the NIR and, some cross-checking with the CRF	An appointed staff member of the Single National Entity (SNE)
CSE co-ordinator (ZSEK)	Overarching QC and QA in connection data entry and calculations for the inventory (data) Assuring the integrity of databases and report tables (Common Reporting Format (CRF)) Emissions reporting and data aggregation into report formats Supporting specialised departments in connection with questions relating to the Central System of Emissions (CSE) and to the report tables Determination of uncertainties (Tier 2), using Monte Carlo simulation	An appointed staff member of the Single National Entity (SNE)
QSE coordinator (QSEK)	Overarching QC and QA throughout the entire reporting process Maintenance and further development of the QSE Management and updating of the QC and QA plans, QC checklists and QSE manual Management for the administration and updating of the inventory plan and of the improvement plan If necessary (for category-specific QC): Definition of category-specific quality targets and of the criteria for their achievement, in consultation with the responsible experts (FV), the QC section representatives and the specialised contact person (FAP).	An appointed staff member of the Single National Entity (SNE)
NaSE co-ordinator (NaSEK)	Ensuring of on-time, requirements-conformal reporting Initiation of overarching measures from the inventory plan Selection of institutions and collection of relevant informational materials and legal agreements Organisation of expert-peer reviews – for example, in the framework of NaSE workshops Ensuring that all relevant inventory information in addition to that archived in the inventory description is centrally archived	An appointed staff member of the Single National Entity (SNE)

Role	Task	Responsible
	Preparation of execution and post-processing of inventory reviews	

1.3.3.1.4 *Organisation for establishing the Quality System for Emissions Inventories*

Procedures for QC/QA measures in the QSE are oriented to the emissions-reporting process described in Chapter 1.2.3. At the same time, quality management is directly linked with the various steps in the inventory process. Suitable QC measures, assigned to the various process players, have been allocated to each step of the inventory-preparation process (cf. Figure 7).

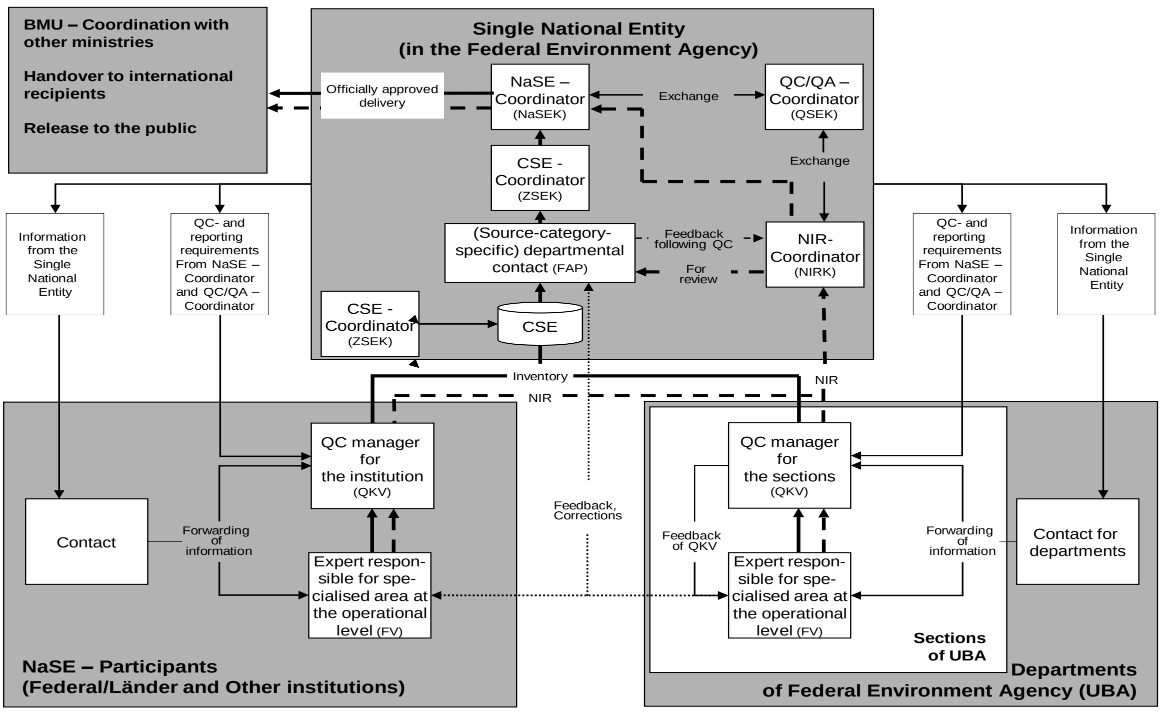


Figure 7: QSE – Roles, responsibilities and workflow

The required quality reviews pursuant to Paragraph 14 (g) of the *Guidelines for National Systems* are provided, in the form of quality checklists and along with data requirements, to the FV, QKV, FAP and NIRK (cf. Table 4). They are completed in the course of the relevant supporting work.

1.3.3.1.5 *Documentation in the Quality System for Emissions Inventories*

The requirements pertaining to the execution, description and documentation of QC/QA measures, as formulated in connection with the minimum requirements for a QC/QA system (cf. Chapter 22.1.2.1), are largely being fulfilled in conjunction with production of the pertinent inventory contributions. For the QSE, a documentation concept was developed that represents all such measures and related actions in an integrated form tailoured to the specific parties and tasks concerned. The various components of such documentation are shown in Figure 8.

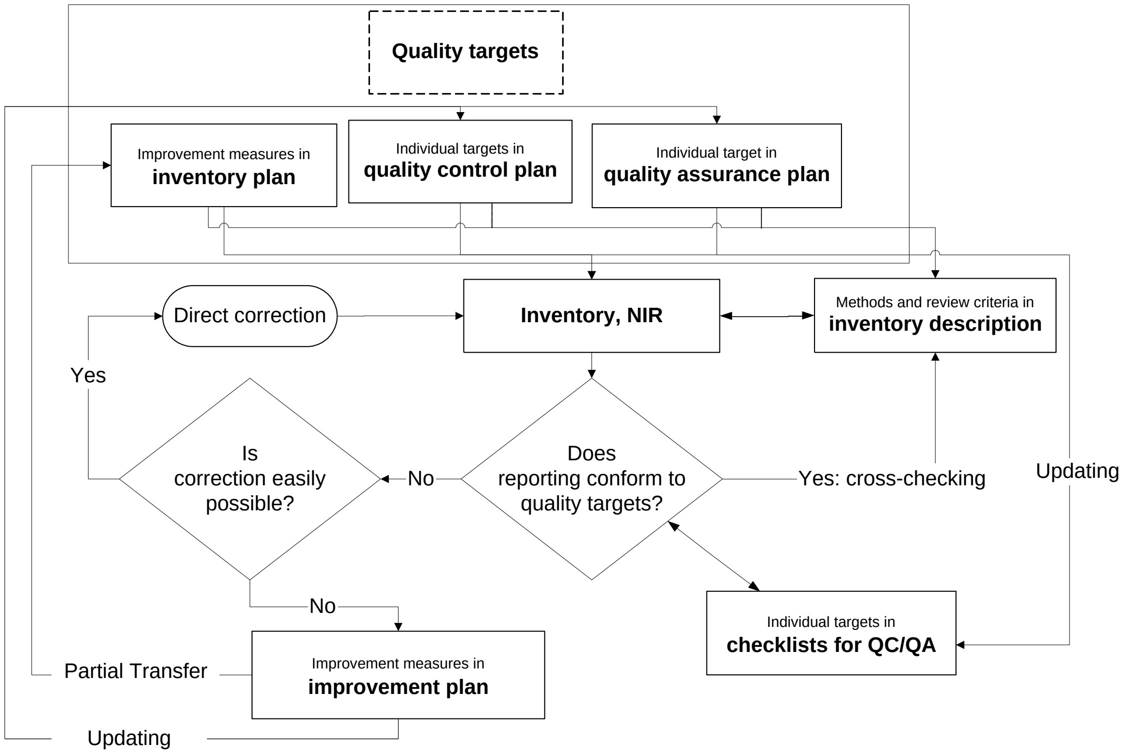


Figure 8: Control and documentation

A general description of the **quality targets** is provided in the QSE handbook; the description is derived from the *2006 IPCC Guidelines (Vol. 1, Chapter 6)*. In addition, individual operational objectives, relative to quality control and quality assurance, have to be derived for the various categories from comparison of the requirements from the *2006 IPCC Guidelines*, the results of independent inventory review, the improvements required in the NIR framework and assessment of inventory realities.

Pursuant to the *2006 IPCC Guidelines (Vol. 1, Chapter 6)* and Paragraph 12 (d) of the *Guidelines for National Systems*, the necessary QC/QA measures for emissions reporting should be summarised in a QC/QA plan. Such a QC/QA plan is to serve the primary purpose of organising, planning and monitoring such QC/QA measures. To permit transparent, effective control of execution and monitoring of measures for achieving these objectives, the measures are set forth in a **quality control plan (QC plan)** and a **quality assurance plan (QA plan)** with respect to specific roles – and, if necessary – specific categories. Quality targets may be focused on the inventory, the reporting process or the QSE itself. In the framework of the quality assurance plan, scheduling of quality-assurance measures is also carried out. Such measures are executed partly by internal staff and mostly by independent, third parties (external). Both plans may be understood as sets of specifications.

As to their structure, the QC and QS plans are combined with the **checklists for quality control and quality assurance**, which are used to review and document successful execution of QC/QA. In this context, quality checks are actually defined not as checks but as quality objectives (data quality objectives pursuant to 2006 IPCC GL, Vol. 1, Chapter 6.5); in each case, either compliance with the objectives must be confirmed or non-compliance must be

justified. These QC/QA checklists have to be completed by the participants in the NaSE[17] in parallel with the inventory preparation process. They facilitate immediate improvements. Where improvements cannot be carried out immediately, they are still useful in providing important information about the quality of the inventory's underlying data, methods and texte). The first time the Federal Environment Agency carried out systematic QC/QA, in the form of checklists, and in co-operation with the NaSE participants, was for the 2006 report. Since then, the checklists for general quality control are filled out every report year, and for all reported categories – i.e. both for key categories and for categories that are not key categories. Since the 2007 report, the checklists have been used in electronic form. Also as of the 2007 report, the general QC checks (formerly, Tier 1 checks) have been expanded to include a number of category-specific QC checks (formerly, Tier 2 checks), for key categories. For the 2008, 2009 and 2010 reports, the checklists for the experts involved in the various specialised areas, and for specialised contact persons, have been comprehensively revised. Such revision has been aimed at further enhancing the clarity, practical usefulness and logical structure of the checklists. To ensure the success of the pertinent improvements, a number of persons from the affected group of persons were selected for inclusion in the revision process. No content-oriented requirements have been modifed as a result. The checklists are reviewed annually for any need for updating, and then they are revised or expanded as necessary. Like the checklists, the QC and QA plan is continually refined. As of the 2013 report, the checklists of the QC/QA section representatives (QKV), which were formerly category-specific, have been consolidated into single overarching checklists for each QKV (i.e. one checklist per QKV). This has been done in order to make the QC/QA process clearer for management personnel and to enhance resource efficiency.
As of the 2015 report, is has been assured that the general checklists meet the revised requirements applying under the 2006 *IPCC Guidelines (Vol.1, Kapitel 6)*. Lacking requirements have been added as necessary.

The two plans and the QC/QA checklists are instruments for reviewing fulfillment of the applicable international requirements, and they make it possible to control inventory quality via initiation of quality assurance measures pursuant to Paragraph 13 of the *Guidelines for National Systems*.

The **improvement plan** documents all potential improvements identified in the framework of the relevant last completed emissions-reporting cycle, as well as the findings that result from independent inventory review. In the plan, such improvements and findings are correlated with feasible corrective measures. The Single National Entity categorises the corrective measures, prioritises them and then, as a rule and via consultations with the relevant responsible experts, integrates them completely within the **inventory plan**. There, they are linked with deadlines and responsibilities. As an annex to the NIR, the inventory plan undergoes a co-ordination and release process. It is thus a binding set of specifications for improvements to be carried out in the coming reporting year.

The Single National Entity also maintains an **inventory description**, a central document record for the various categories. The description covers all key aspects of inventory preparation. It includes descriptions of all work that pertains to specific categories and that is

[17] These include responsible experts (FV), specialised contact persons (Fachliche Ansprechpartner – FAP), QC/QA section representatives (QKV – quality control managers) and the coordinator for the national inventory report (Koordinator für den Nationalen Inventar Report – NIRK)

relevant to preparation of category-specific inventories. The inventory description consists of a server-based folder (directory) system that is available both on mobile devices and on the desktops of the persons working in the framework of emissions reporting. The obligation to prepare defined documentation was introduced in the Federal Environment Agency via an in-house directive (cf. Chapter 1.3.3.1.1). It provides the key basis for archiving inventory information pursuant to the provisions of Paragraph 16 (a) of the *Guidelines for National Systems*.

- For a range of reasons, the documentation concept, in a departure from Paragraph 17 of the *Guidelines for National Systems*, does not provide for an exclusively central archive. The key reasons for this decision included the fact that the body of data that provides the basis for calculating the German inventory is extensive, and non-centralised.
- In addition, external parties hold some of the responsibility for the data,
- and confidentiality criteria preclude, for legal reasons, provision of certain data items, for archiving purposes, to a central agency.

The inventory description contains information as to the locations of documents that are not centrally stored.

1.3.3.1.6 The QSE handbook

The international requirements for quality assurance and quality control measures in emissions reporting have been set forth, for the National System of Emissions Inventories (NaSE) in Germany, in the "Handbook for quality control and quality assurance in preparation of emissions inventories and reporting under the UN Framework Convention on Climate and EU Decision 525/2013/EC" ("Handbuch zur Qualitätskontrolle und Qualitätssicherung bei der Erstellung von Emissionsinventaren und der Berichterstattung unter der Klimarahmenkonvention der Vereinten Nationen sowie der EU Entscheidung 280/2004/EG". That document, which is binding for the Federal Environment Agency, describes the Quality System for Emissions Inventories (QSE).

The QSE handbook has entered into force via an in-house directive of the Federal Environment Agency (cf. Chapter 1.3.3.1.1). It has been published, along with pertinent, co-applicable documents, in the Federal Environment Agency's intranet.

1.3.3.1.7 Support for the UNFCCC review

In addition to the Federal Environment Agency's own quality control and assurance measures, the UNFCCC review provides important impetus for inventory improvement. It is thus in the Single National Entity's own interest to fulfil the provisions of Paragraphs 16 (b) and (c) regarding provision of archived inventory information for the review process and for responding to questions of expert review groups. This relationship has been given priority in the design of the QSE.

1.3.3.1.8 Use of EU ETS monitoring data for improvement of GHG-emissions inventories

Monitoring data from European emissions trading will be used to improve the quality of annual national emissions inventories with respect to categories that include installations subject to reporting obligations under the CO_2 Emissions Trading Scheme (ETS).

The comparisons have confirmed, in principle, the usefulness of such comparisons for verifying individual categories and identifying data gaps. A formalised procedure, with defined deadlines and workflow, has been agreed for their regular use and for the relevant annual required data exchanges.

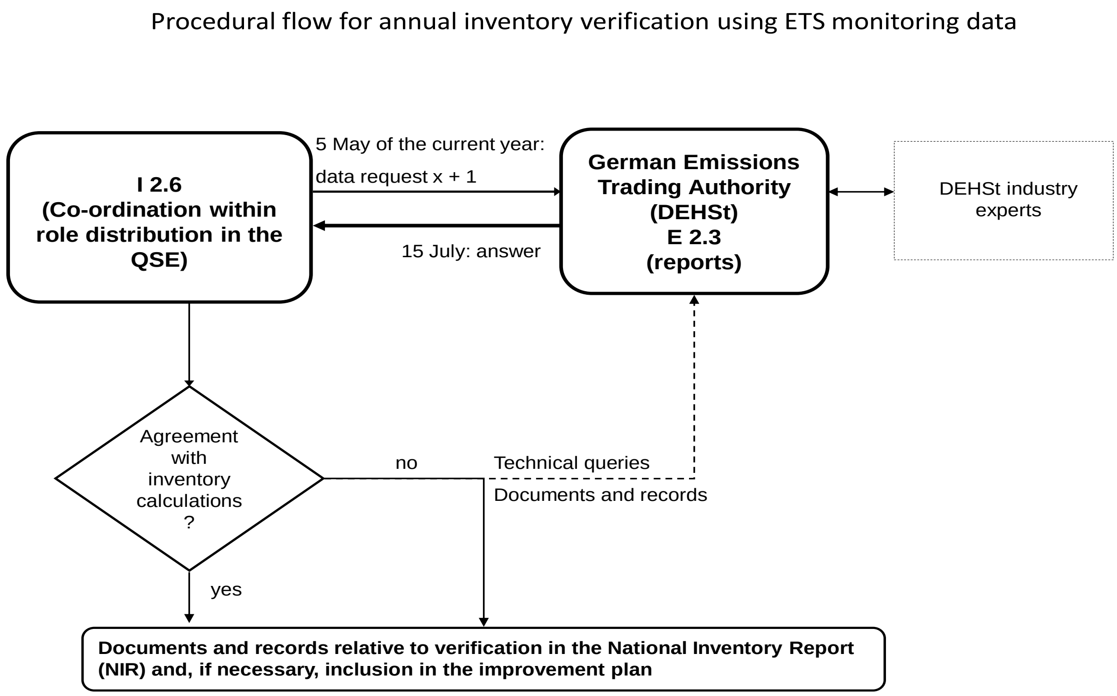


Figure 9: Procedural flow for annual inventory verification using ETS monitoring data

Regarding the details of data use in QC/QA, cf. also Chapter 1.6.2.1 Verification in selected categories.

1.4 Short, general description of the methods and data sources used

1.4.1 Greenhouse-gas inventory

1.4.1.1 Data sources

1.4.1.1.1 Energy

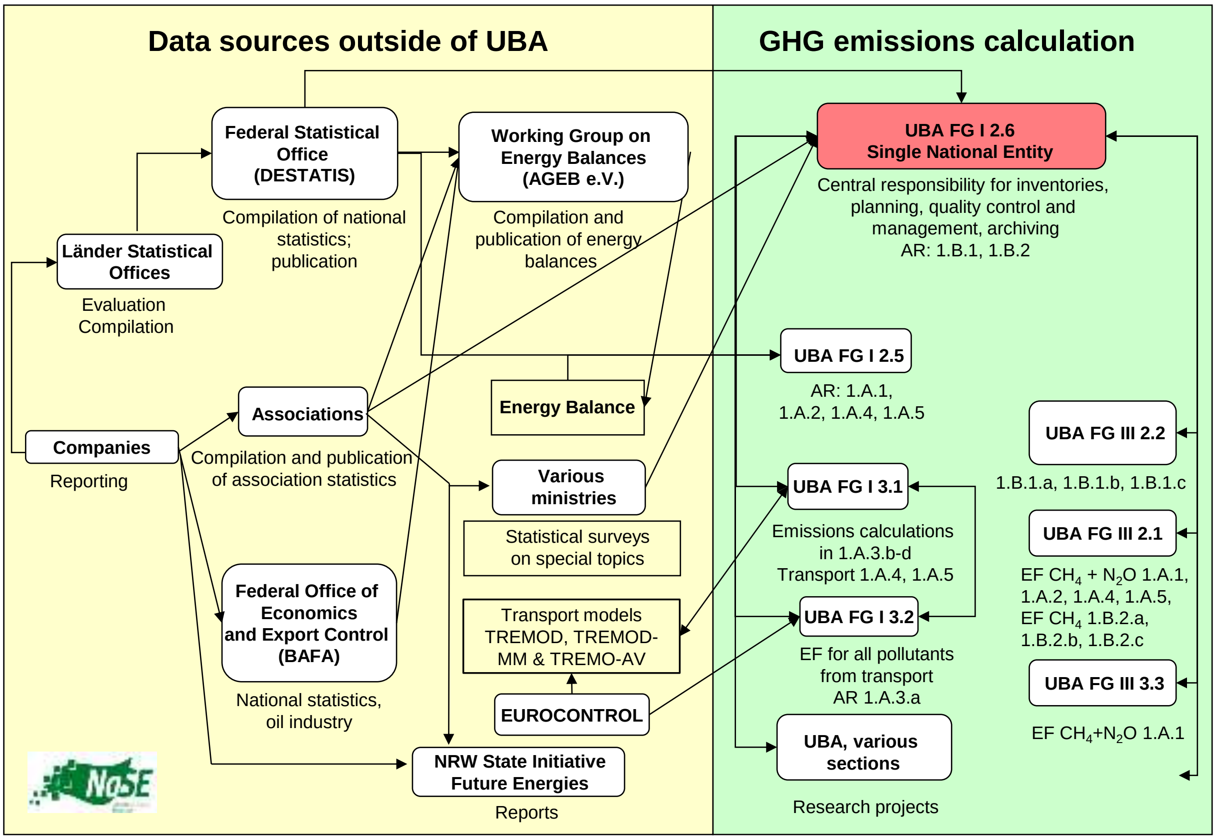


Figure 10: Responsibilities and data flows for calculation of greenhouse-gas emissions in the energy sector

In all likelihood, the most important data sources for determination of activity data for category 1.A are the *"Energy Balances of the Federal Republic of Germany"* ("Energiebilanzen der Bundesrepublik Deutschland"), hereinafter referred to as: Energy Balance), which are published by the *Working Group on Energy Balances* (Arbeitsgemeinschaft Energiebilanzen - AGEB). An Energy Balance provides an overview of the links within Germany's energy sector, and it supports breakdowns in accordance with fuels and categories. The data for Energy Balances come from a wide range of other sources.

The AGEB was commissioned to prepare the Energy Balances for the years 2007 – 2012. Subsequently, it was commissioned by the Federal Ministry for Economic Affairs and Energy (BMWi) to prepare the Balances for the years 2013-2017. In such commissioning, the AGEB was obligated to apply minimum requirements relative to quality assurance for the National System. For the Energy Balances of recent years, the German Institute for Economic Research (DIW) and the firm of Energy Environment Forecast Analysis GmbH Co. KG have prepared quality reports detailing the quality control and assurance measures applied. As of 2012, the Working Group on Energy Balances (AGEB) provides a joint quality report for the Energy Balance (cf. Chapter 18.4.1). Also as of 2012, the AGEB prepares an "Energy-Data Action Plan for inventory improvement" ("Aktionsplan Energiedaten Inventarverbesserung"; cf. Chapter 18.5) that outlines actions to be taken to address the criticism that emerged from the inventory review. This action plan fulfills the action-plan requirement set forth in Paragraph 39 of the 2011 review report (FCCC/ARR/2011/DEU).

Along with the main Energy Balance, a *Satellite Balance of Renewable Energies* (Satellitenbilanz Erneuerbare Energieträger; hereinafter referred to as: Satellite Balance) also appears. This balance describes the growth and use of renewable energies in detail. The Satellite Balance appears together with the Energy Balance.

The *Federal Statistical Office* is another important source of data for determination of activity data. The resources of that office that are used in the present context include the *Fachserien 4 (technical series 4) Reihe (sub-series) 4.1.1, Reihe 6.4,* and, for waste data, Fachserie 19. These data are published relatively promptly after collection (about one year), and they are broken down finely in accordance with various areas of the manufacturing sector. To support further data differentiation, and clarification of details, the Federal Statistical Office provides special evaluations.

For the iron and steel sector, as of the 2012 report, data of the Wirtschaftsvereinigung Stahl German steel industry association are being used. Inter alia, these data replace the so-called "BGS form" (Fuel, gas and electricity industries of blast furnaces, steelworks and rolling mills; and forging plants, press works and hammer mills, including the various other plants (without their own coking plants) locally connected to such operations), a section of the "Fachserie 4, Reihe 8.1", publication of which was discontinued as of 31 December 2009.

The series STATISTIK DER KOHLENWIRTSCHAFT ("Coal industry statistics"), especially its annual publication "Der Kohlenbergbau in der Energiewirtschaft der Bundesrepublik Deutschland" ("Coal mining in the energy sector of the Federal Republic of Germany"), is used as an additional data source. In addition, the special evaluations provided by the Bundesverband Braunkohle (DEBRIV; federal German association of lignite-producing companies and their affiliated organisations) are used for differentiation of the different types of raw lignite coal that are burned. Furthermore, DEBRIV provides the necessary data for calculation of fuel inputs for lignite drying.

Another data source consists of the *"Petroleum Data" of the Association of the German Petroleum Industry (MWV)*, which include data on petroleum production and consumption in Germany, broken down by various production, transformation and utilisation sectors. These statistical data, which are a key basis for the National Energy Balance, are published within just a few months after the relevant survey and are thus a relatively current source.

The quantities of secondary fuels used for energy generation (listed under CRF 1.A.2) are taken from the annual report of the German Pulp and Paper Association (Verband der Papierindustrie) and from reports of the German Cement Works Association (Verband der Zementindustrie – VDZ).

The emission factors for the stationary combustion systems described in category 1.A have been obtained mainly from ETS monitoring data of the German Emissions Trading Authority (DEHSt) and from research projects initiated by the Federal Environment Agency.

For collection of transport emissions data (1.A.3), *Official Mineral-oil Data* (amtliche Mineralöldaten) of the *Federal Office of Economics and Export Control (BAFA)* and *Petroleum*

Data (Mineralöl-Zahlen) of the *Mineralölwirtschaftsverband e.V. Association of the German Petroleum Industry (MWV)* e.V. are used, in addition to Energy Balance data.

For collection of transport emissions data (1.A.3), *Official Mineral-oil Data* (amtliche Mineralöldaten) of the *Federal Office of Economics and Export Control (BAFA)* and *Petroleum Data* (Mineralöl-Zahlen) of the *Mineralölwirtschaftsverband e.V. Association of the German Petroleum Industry (MWV)* e.V. are used, in addition to Energy Balance data.

Road-transport emissions are calculated primarily with the TREMOD model ("*Transport Emission Estimation Model*"; currently: Version 5.5.2, IFEU, 2014)[18]. For calculations carried out in TREMOD, extensive basic data from generally accessible statistics and special surveys are used, co-ordinated, and supplemented. A precise description of the data sources for emission factors is provided by the "Handbook of road-traffic emission factors" ("Handbuch Emissionsfaktoren des Straßenverkehrs") (HBEFA, Version 3.2) (INFRAS, 2014).

For air transports, in addition to data of the aforementioned sources, data of *EUROCONTROL, the European Organisation for the Safety of Air Navigation*, and of the *Federal Statistical Office* are used: Year-specific split factors, determined on the basis of actual aircraft movements, are used to break down fuel consumption and emissions data by national and international air transports. For years as of 2003, the split factors are provided by Eurocontrol. For all earlier years, they are derived via aircraft-movement data (numbers of take-offs and landings) collected by the Federal Statistical Office. The aircraft-movement data collected by the Federal Statistical Office are also used to break down consumption and emissions data in accordance with the different phases of flight. Further processing of the many different types of data received takes place within TREMOD-AV, a separate module of the TREMOD database. Country-specific consumption and emissions data provided by Eurocontrol are currently being used only to verify our own figures. Data on emissions of other mobile sources (in 1.A.4 and 1.A.5.b) are also collected from figures of the Working Group on Energy Balances (AGEB), of BAFA and of the Association of the German Petroleum Industry (MWV). Military transports (1.A.5.b) play a special role in this context since, as of 1995, the consumption data for those transports are no longer listed separately in the Energy Balances. The consumption data for military land and air transports are obtained from the official petroleum data of BAFA, while data for military sea transports are obtained from a model developed by the Federal Maritime and Hydrographic Agency (BSH) (BSH, 2015)

Due to a lack of separate figures on consumption of biofuels in construction-related and agricultural transports, on mobile residential sources and on military transports, the relevant annual quantities are calculated on the basis of the official admixture quotas.

Data for categories of category 1.B.1 are taken from publications of Statistik der Kohlenwirtschaft e.V. (coal-industry statistics), the Federal Ministry for Economic Affairs and Energy (BMWi), the DEBRIV Federal German association of lignite-producing companies and their affiliated organisations, Deutsche Montan Technologie GmbH (DMT), the German Society for Petroleum and Coal Science and Technology (DGMK) and Interessenverband Grubengas e.V. (IVG; association for the pit-gas sector).

18 To make it possible to derive and assess reduction measures, energy consumption and CO_2 emissions for the various vehicle categories are also calculated with TREMOD. The resulting values are subsequently checked against total consumption and total CO_2 emissions.

The publication "Statistik der Kohlenwirtschaft" (coal-industry statistics) is especially important in this context. It is processed with the help of federal and Land (state) ministries, including their authorities (such as supreme state mining authorities), and with use of reports and expert opinions of the "Landesinitiative Zukunftsenergien" NRW ("NRW State Initiative for Future Energies"; here, the AG Grubengas mine-gas working group). Inventory preparation is co-ordinated with the support of the Gesamtverband Steinkohle (Association of the German hard-coal mining industry).

Data for categories in category 1.B.2 are taken from publications of the *Federal Statistical Office*, the Association of the German Petroleum Industry (MWV), the German Society for Petroleum and Coal Science and Technology (DGMK), the Association of the petroleum and natural-gas industry (Wirtschaftverband Erdöl und Erdgasgewinnung e.V. – WEG), the German Technical and Scientific Association for Gas and Water (DVGW), the Federal association of the German gas and water industry (Bundesverband der deutschen Gas- und Wasserwirtschaft – BDEW; gas statistics) and the German Emissions Trading Authority (DEHSt).

1.4.1.1.2 Industrial processes

Activity data for the mineral industry are obtained primarily from association statistics. The data for the cement industry (2.A.1) were provided by the German Cement Works Association (Verband der Zementindustrie – VDZ), especially by that association's research institute, as well as by the Federal association of the German cement industry (Bundesverband der Deutschen Zementindustrie e.V. - BDZ). For the most part, the data in question consist of data published in the framework of CO_2 monitoring under the industry's voluntary climate-protection commitment. The figures for lime and dolomite-lime production (2.A.2) are collected by the German Lime Association (BVK) on a per-plant basis and then provided annually in aggregated form. Glass-production figures (2.A.3) are taken from the regularly published annual reports of the Federal glass industry association (Bundesverband Glasindustrie), although relevant orientational figures on glass recycling are taken from other statistics. The production figures for the ceramics industry (2.A.4.a) are calculated with the help of official statistics and with conversion factors provided by the German brick and tile industry association (Bundesverband der Ziegelindustrie) berechnet. The figures for soda ash use (2.A.4.b) are estimated by experts of the Federal Environment Agency. .

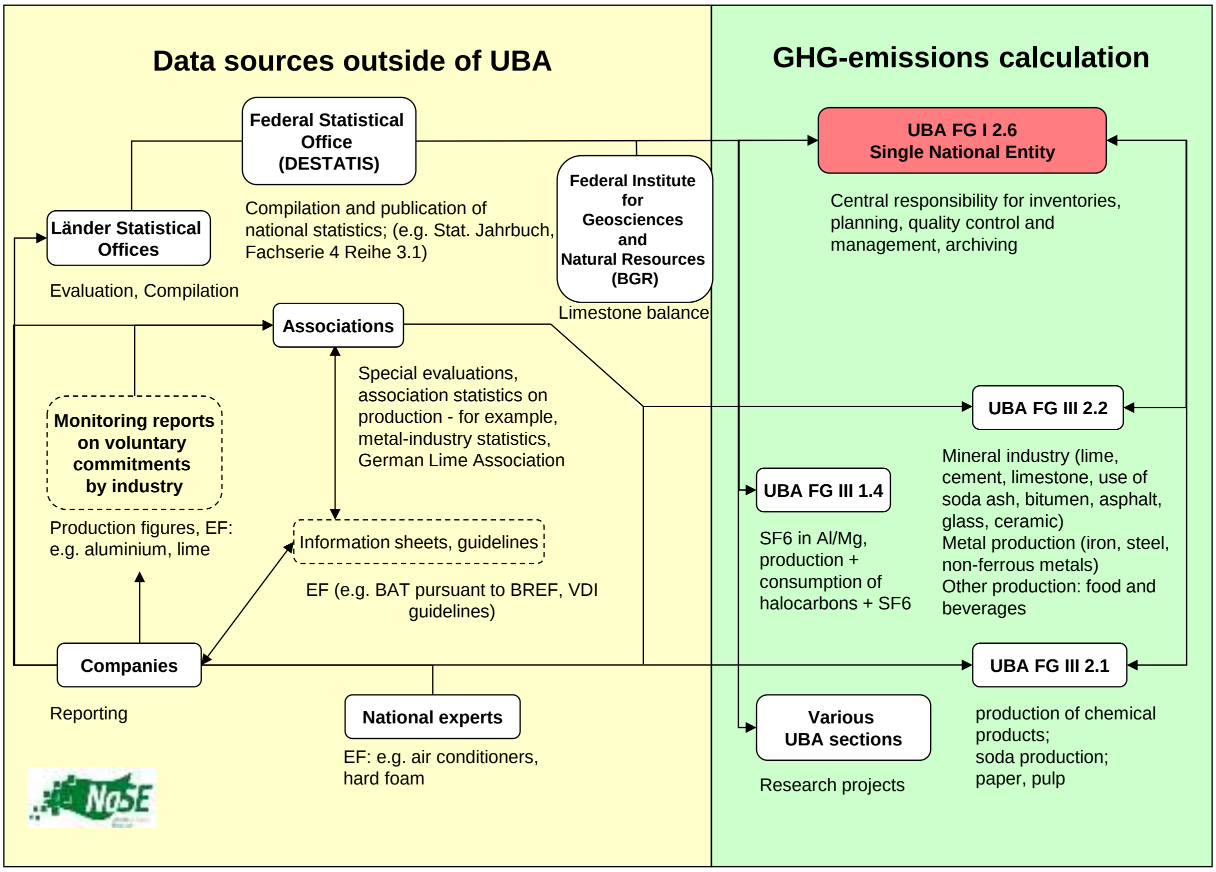


Figure 11: Responsibilities and data flows for calculation of greenhouse-gas emissions in the area of industrial processes

A range of different sources are used to determine emission factors for the mineral industry. The emission factor used for calculation of emissions from cement-clinker production (2.A.1) is based on a calculation of the German Cement Works Association (VDZ) carried out by aggregating plant-specific data. CO_2 emissions from lime production (2.A.2) and from soda-ash use (2.A.4.b) are calculated with the help of stoichiometric factors. The CO_2-emission factors for various types of glass (2.A.3) have been derived from glass-composition data, while CO_2-emission factors for the ceramics industry (2.A.4) have been derived, by Federal Environment Agency experts, from raw-material inputs.

The activity data for category 2.B Chemical industry are determined from activity data of the *Federal Statistical Office* (*Fachserie 4 Reihe 3.1*) and directly from figures of industry associations and producers. Some of these data are confidential. The relevant emission factors have been determined by experts in the Federal Environment Agency, via research projects or by the pertinent producers. Until 2008, activity data for 2.B.1 Ammonia production and 2.B.2 Nitric acid production were collected by the *Federal Statistical Office*. Since 2009, data for ammonia and nitric-acid production have been collected by producers themselves – plant-specifically, on the basis of an agreement with the chemical industry and for the entire time series as of 1990. These data are forwarded to the association, which aggregates them and forwards them, in anonymised form, to the Federal Environment Agency. For this purpose, in addition to determining the applicable activity data, the producers also determine the applicable emissions for 2.B.1 and the applicable emission factors for 2.B.2. Until the mid-1990s, plant-by-plant activity data were supplied for 2.B.3 Adipic acid production. The default emission factor for N_2O was applied to that data. Now, plant operators are supplying emissions data directly to the Federal Environment Agency, on a confidential basis. For the area of adipic-acid production, data delivery has also been assured for the long term, via an agreement from 2009. Producers in Germany find the IPCC's default emission factors for NO_X, CO and NMVOC rather puzzling. This is the reason why emissions of these substances have not been reported to date. In 2.B.4, only emissions from caprolactam production play a significant role. Through 2008, the relevant activity data were provided by *the Federal Statistical Office*. Since then, as a result of a harmonisation of national production statistics with international requirements, caprolactam is no longer listed separately, and thus the confidential activity data have been carried forward. The relevant emission factors have been determined via a research project and information provided by producers. Since there is only one calcium carbide (2.B.4) producer in Germany, the relevant data are confidential. The Federal Environment Agency obtains these data directly from the producer. The CO_2 emissions from titanium dioxide production are not reported, because they lie below the applicable threshold (2.B.6). The *Federal Statistical Office* determines the total amounts of soda ash (2.B.7) produced in Germany. The pertinent emission factors are derived from the ETS monitoring data of the German Emissions Trading Authority (DEHSt). The activity data for production of the products listed under 2.B.8 Petrochemicals and carbon black production are obtained from statistics of the *Federal Statistical Office*. Some of the data are subject to confidentiality. The emission factors are obtained from experts' estimates, research projects and default figures provided in the IPCC Guidelines. In the area of production of halocarbons and SF_6 (2.B.9), data are obtained from *producers' figures and surveys of producers*. For the most part, activity data are researched in the framework of research projects, directly in accordance with the inventory's requirements. In some cases, producers supply only emissions data. Only small numbers of companies are involved in the various sub- source categories, and thus data in these areas are confidential. Under 2.B.10 Other, emissions of precursor substances from production of sulphuric acid and fertilisers are reported. The activity data are obtained from information provided by producers and from data of the Federal Statistical Office. The emission factors are obtained from experts' estimates and research projects.

The activity data for the metal industry (2.C) are provided by the *Federal Statistical Office,* by the relevant associations (Steel Institute VDEh, Wirtschaftsvereinigung Metalle (metals industry association) and Gesamtverband der Aluminiumindustrie (aluminium industry association) and by sellers of industrial gases. The emission factors for the metals industry (2.C) are normally calculated by experts in the Federal Environment Agency; in some cases, emission factors are provided by industrial associations or IPCC default values are used.

One exception in this regard is the category Ferroalloys (2.C.2); for it, activity data from statistics of the UK Geological Survey are used, while the relevant emission factors are taken from the results of a research project (in some cases, IPCC default values are also used).

In category 2.D Non-energy-related products from fuels and solvents, the activity data have been taken from published surveys of the Federal Statistical Office and of other federal authorities (for production and foreign-trade statistics, and for petroleum statistics) and of relevant associations (the VDD industry association for bitumen paper and bitumen roof sheeting; the German asphalt industry association (Deutscher Asphaltverband – DAV)). The activity data are supplemented with industry statistics and information supplied by experts.

The emission factors have been taken from various sources. For example, those for lubricant and paraffin-wax use have been calculated by the relevant expert unit in the Federal

Environment Agency, with the help of IPCC default values. NMVOC emissions from lubricant use have been given only as CO_2 emissions, however, in keeping with the 2006 IPCC Guidelines. The emission factors for production and laying of bitumen paper and bitumen roof sheeting (2.D.3), and for production of asphalt for road paving (2.D.3), refer only to NMVOC, and they have been taken from research reports.

Emission factors, along with other parameters that enter into calculation of emissions from solvent use, are taken from national studies, experts' opinions and research projects directly commissioned by the Federal Environment Agency; in some cases, they are also based on information provided by experts in the context of dialogs with industry.

More-precise information regarding emission factors is provided in the method descriptions for the individual categories. The activity data for the electronics industry (2.E), for product use as substitutes for ODS (2.F) and for other product production and use (2.G) have been determined from information provided by producers and associations, from surveys of the Federal Statistical Office and of other federal authorities and with the help of calculation models. In individual cases, producers provide emissions data directly. The data are classified into several subcategories. Product use as ODS substitutes is subdivided into production, use and disposal emissions. In these categories as well, the data in some areas are subject to confidentiality requirements.

Emission factors for fluorinated greenhouse gases are obtained in part from national and international fact sheets and directives or via surveys of experts; where necessary, IPCC default values are used.

In the area of 2.H.1 Other production: Pulp and paper production, data from the production report of the German Pulp and Paper Association (Verband Deutscher Papierfabriken – VDP) are used. In the area of 2.H.1 Other production: Food and beverages, data of the Federal Food Industry Association (Bundesvereinigung der Deutschen Ernährungsindustrie; BVE), of the Federal Statistical Office (Statistisches Bundesamt) and of the Federal Ministry of Food and Agriculture (BMEL) are used. The emission factors have been obtained from a research project that was completed in 2008.

1.4.1.1.3 Agriculture

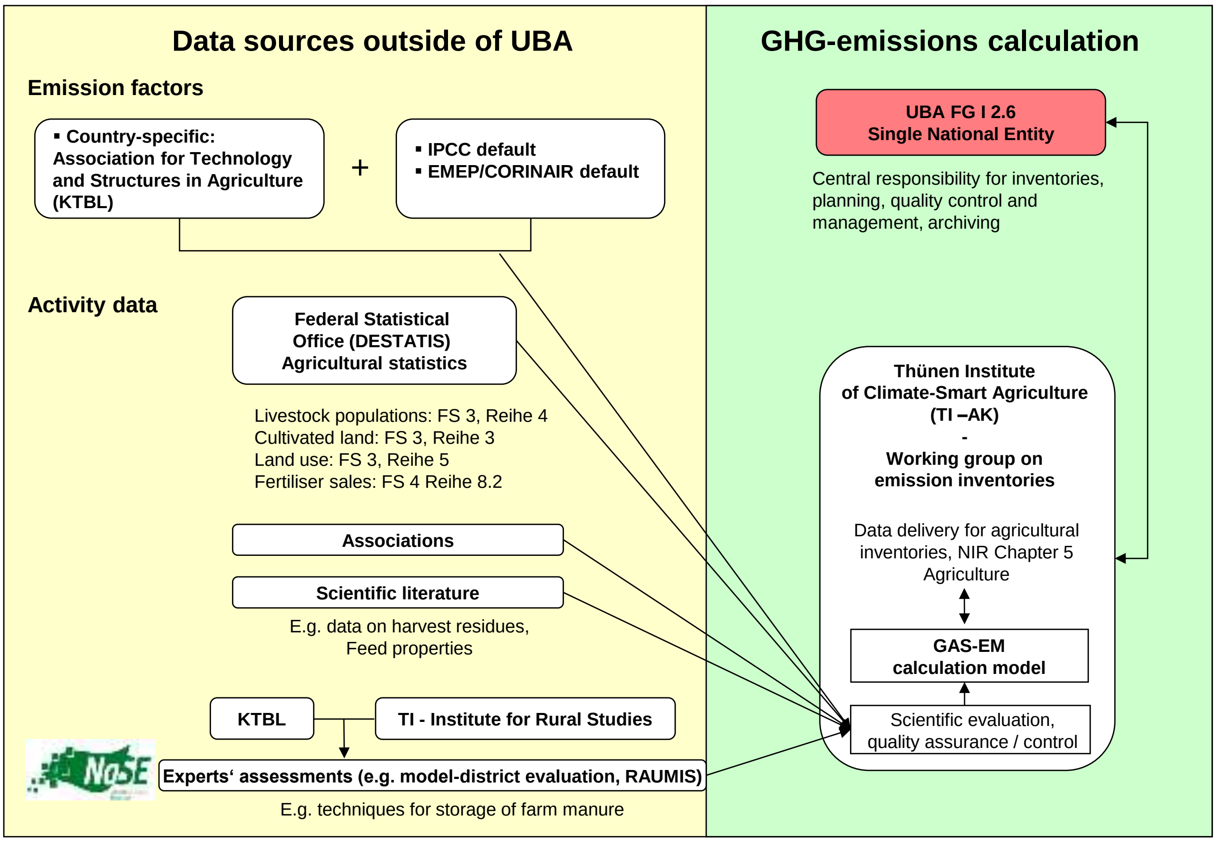


Figure 12: Responsibilities and data flows for calculation of greenhouse-gas emissions in the area of agriculture

Emissions calculations for category 3 (Agriculture) are carried out by the Thünen Institute (TI). For calculation of agricultural emissions in Germany, the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and the Federal Ministry of Food and Agriculture (BMEL) initated a suitable joint project, in the framework of which the former Federal Agricultural Research Institute (FAL) developed a modular model for relevant spread-sheet calculation (GASeous Emissions, GAS-EM) (DÄMMGEN et al, 2002 & HAENEL et al. 2012). The BMUB and BMEL now have a framework ministerial agreement in place for management of relevant data and information exchange and for operation of a joint database at the UBA and the FAL.

Agricultural statistics of the Federal Statistical Office are another important data source for calculation of agricultural emissions. Animal statistics have been obtained from the *Federal Statistical Office* (*FEDERAL STATISTICAL OFFICE,* FS3 R4); other Fachserien (technical series) provide data on amounts of fertiliser sold and agricultural land under cultivation. In some areas, such data are supplemented by figures from the pertinent literature (for example, crop residues and recommended fertiliser quantities). Additional data are available from experts' assessments (for example, an evaluation of model districts with regard to techniques for storing farm fertilisers).

In many areas, calculations for the agriculture sector are based on highly differentiated activity data obtained via national data sources. Also in many areas, such data are combined with the standard emission factors given in the 1996b and 2006 IPCC Guidelines or the EMEP/EEA manual of the United Nations Economic Commission for Europe (UN ECE).

1.4.1.1.4 Land-use changes and forestry

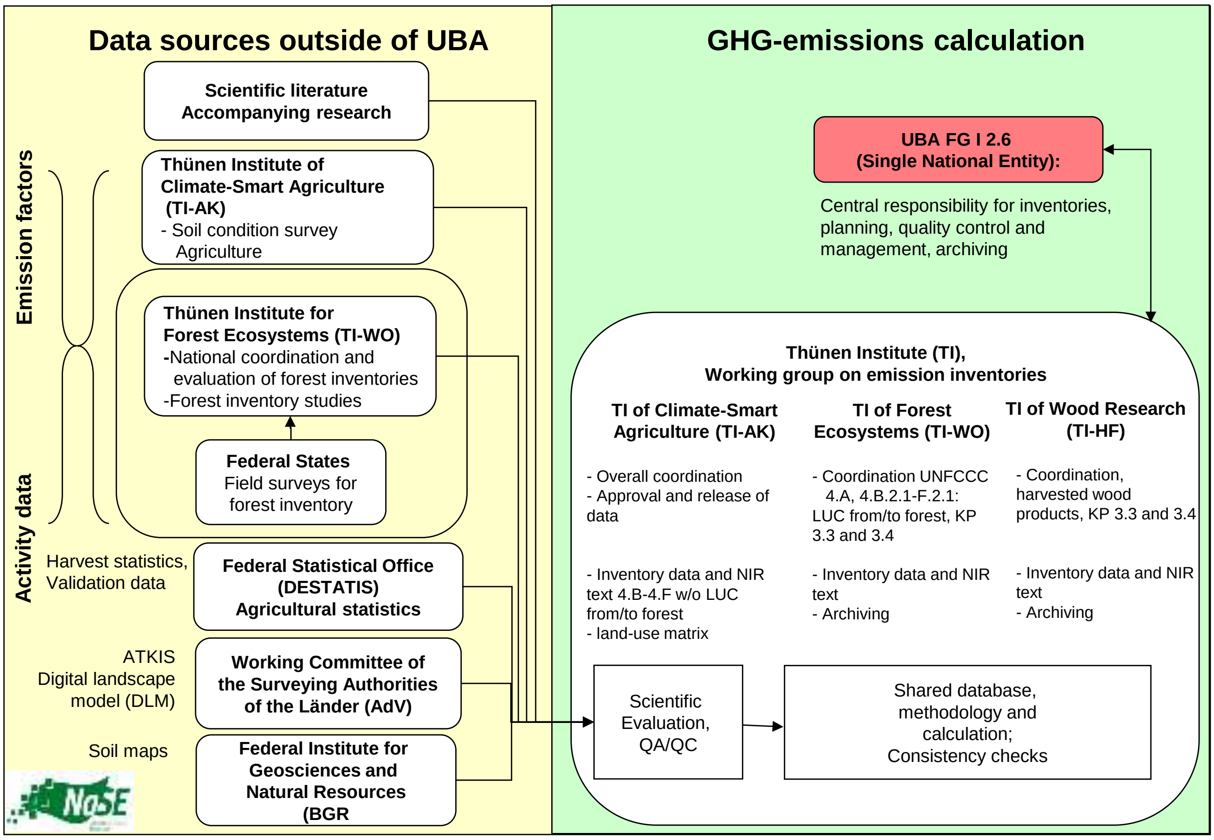


Figure 13: Data flows for calculation of greenhouse-gas emissions from the areas of land-use changes and forestry (LULUCF) and KP-LULUCF

In the 2012 Submission, a consistent, unified method was introduced for taking account of land-use changes in the LULUC sector and the forestry sector. The method expands the existing sample-based system for determining forest-land areas, and land-use changes to and from forest land, for all land-use categories and change types.

Soil carbon stocks are estimated with the help of soil maps (differentiated to show usages) and soil-profile data provided by the Federal Institute for Geosciences and Natural Resources (BGR), while use-change-related changes in these stocks are estimated on the basis of changes in the mean stocks per land-use category.

Changes in biomass carbon stocks are estimated on the basis of harvest statistics, the main survey on soil use (Bodennutzungshaupterhebung) and specific factors given in the pertinent scientific literature (and used in conjunction with area data). Emissions from liming of soils are determined with the help of data, taken from Federal fertiliser statistics, on domestic sales of mineral fertilisers that contain lime and other nutrients. The fertiliser industry is legally required to disclose its sales.

Projects for improvement of activity data, and especially for determination of country-specific emission factors for carbon and nitrogen, and for CO_2, CH_4 and N_2O – for example, the project "Organic Soils" (since 2009), the agricultural soil survey (Bodenzustandserhebung Landwirtschaft; since 2011) and others – will help validate and improve national estimates of emissions and removals.

1.4.1.1.5 Waste and wastewater

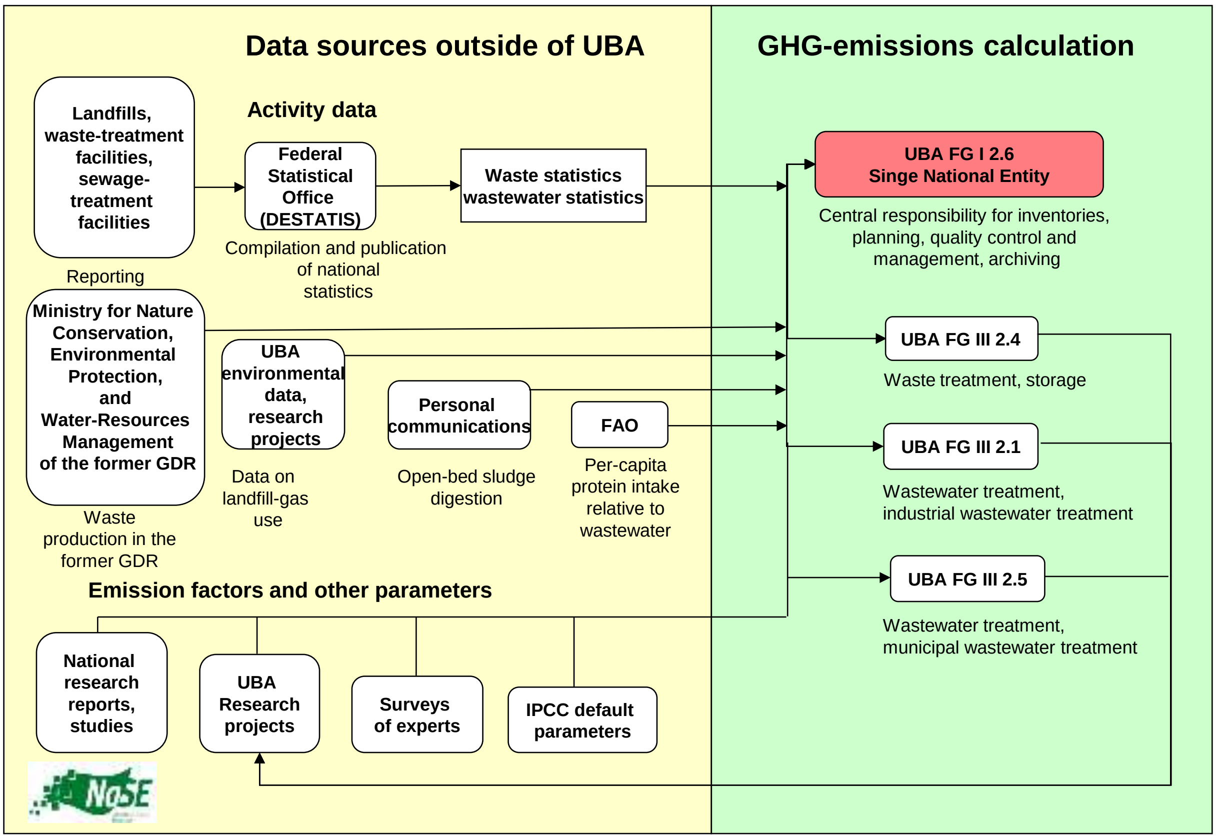


Figure 14: Data flows for calculation of greenhouse-gas emissions from the area of waste and wastewater

Federal Environment Agency Section FG III 2.4 *Waste technology, waste technology transfer* is responsible for selecting the methods, parameters and data for calculating emissions from the waste sector. In recalculation of landfill emissions in 2003 (development of the Tier 2 method for the Federal Republic of Germany), and in refinement of the Tier 2 method in 2006, the Federal Environment Agency was supported by a research project (ÖKO-INSTITUT, 2004b).

Activity data in the waste sector are drawn mainly from published data of the Federal Statistical Office, which provides detailed, disaggregated time series. The section on waste provides precise information as to what statistical series and sources were used. The Federal Statistical Office has not published any data on amounts of waste produced in the former GDR. In this area, an official source of the former GDR's ministry for nature conservation, environmental protection and water-resources management was used. The calculations relative to landfill-gas use are based on data from the Energy Balances and from Fachserie 19 of the Federal Statistical Office. The database for landfill-gas use was updated in the framework of the 2010 In-Country Review. Statistical data on gas collection at landfills in the follow-on care phase have been collected since 2012.

The emission factors and other parameters that enter into calculation of emissions from waste landfilling, from mechanical-biological waste treatment and from composting were taken from national studies and research reports conducted/prepared in research projects commissioned directly by the Federal Environment Agency. IPCC default parameters were also used for this purpose. Selected experts were also consulted regarding a few of the relevant parameters (for example, half-life selection). The relevant chapter presents the sources for the various parameters, in detail.

The Federal Environment Agency's Section for *General Aspects, Chemical Industry, Combustion Plants* (III 2.1) is responsible for selecting the methods, parameters and data for calculating emissions from the industrial wastewater / sewage sludge handling sector (5.D.2). The Federal Environment Agency's Section III 2.5 *Monitoring Methods, Waste Water Management* is responsible for selecting the methods, parameters and data for calculating emissions from the municipal wastewater handling sector (wastewater and sewage sludge) (5.D.1).

Activity data in the wastewater sector are drawn mainly from published data of the Federal Statistical Office, which provides detailed, disaggregated time series. The section on wastewater provides precise information as to what technical series and sources were used. The data on per-capita protein intake are taken from FAO data.

The emission factors and other parameters that enter into calculation of emissions from wastewater treatment were taken from national studies and research projects commissioned directly by the Federal Environment Agency. IPCC default parameters are also used. Various experts were consulted directly regarding a few parameters and methodological issues (for example, production of CH_4 emissions in aerobic wastewater-treatment processes).

1.4.1.2 Methods

The methods used for the individual categories are outlined in the overview tables for the various categories and in summary tables 3s1 and 3s2 of the CRF reporting tables. In addition, detailed descriptions are provided in the relevant category chapters.

A distinction is made between calculations made with country-specific ("CS") methods and calculations made, in the various categories, with IPCC calculation methods of varying degrees of detail (of varying "Tiers")[19]. The manner in which a calculation is assigned to the various IPCC methods depends on the pertinent category's share (expressed as equivalent emissions) of total emissions. Such assignment is carried out via an instrument known as "key-category analysis" (cf. Chapter 1.5 in this regard).

NMVOC emissions from solvent use, converted into indirect CO_2, are calculated on the basis of a product-consumption approach pursuant to the IPCC Guidelines 2006. A similar procedure is used in the area of lubricant use.

1.4.2 KP LULUCF activities

The data sources and methods used for KP reporting do not differ from the data sources and methods used for reporting for categories with CRF categories 4.A, 4.B and 4.G in the UNFCCC framework. There are thus no differences with regard to the present purpose. Cf. also Chapter 1.4.1.1.4 and Chapter 5 and Annex Chapter 19.3.

19 Tier 1 refers to the simpler calculation methods that may be used with fewer input data, whereas Tier 2 and Tier 3 require more differentiated input data and hence generally lead to more accurate results.

1.5 Brief description of key categories

1.5.1 Greenhouse-gas inventory (with and without LULUCF)

The key categories were identified by applying two Approach 1 procedures, Level (for the base year, for 1990 and for the most current year) and Trend (for the most current year, as compared to the base year), to German greenhouse-gas emissions. In addition, the Approach 2 procedure was used. In keeping with the pertinent IPCC specifications for the Approach 1 procedure, analysis focussed both on emissions from sources and on removals of greenhouse gases in sinks. The analyses are first carried out solely for emissions from the sources listed in Annex 1 of the UN Framework Convention on Climate Change and, then, in a second step, for storage of greenhouse gases in sinks. All specified key categories result either from level analysis, or from trend assessment, or from Approach-2 key-category analysis on the basis of current uncertainties determination. No new key categories have been added as a result of assessment of qualitative aspects (explanations regarding this aspect are provided in Annex Chapter 17.1.2).

For the current report, the Approach 1 procedure identified 46 source categories, out of a total of 151 source and sink categories studied, as key categories. Only 28 of these were identified, by both trend and level analysis, as key categories. In addition, 11 categories were identified as key categories solely by trend analysis, and 7 categories were so identified solely by level analysis. Via the Approach 2 procedure, 6 additional key categories were identified (cf. Table 8).

Ultimately, 52 key categories were identified. These are summarised in Table 5.

Table 5: Number of categories and key categories

Category	**120**		
			Key categories
by Level	Level & Trend	Trend	
7	28	11	**46 (Tier 1)** **+6 (Tier 2)** **52 (total)**

Table 6 provides an overview of the results of Tier-1 key-category analysis. Table 8 shows the additional key categories identified via Tier 2 analysis. Annex 1 (Chapter 17) of this report presents detailed explanations of the key-category analysis carried out.

A few changes have occurred. with respect to the results obtained in the previous year, as a consequence of the shift to the 2006 IPCC GL. The changes, which are the result of methodological modifications, new emission sources and new allocations in the new CRF structure, have been considerable, and thus this year we have not included a description of changes with respect to the previous year.

Germany uses all recommended procedures for identifying and evaluating source categories. The IPCC Guidelines require 95% of emissions from sources / removals in sinks to be classified in key categories. In keeping with the fact that Germany identifies key categories by combining the results of all analysis procedures and evaluations, emission-causing activities accounting for about 98 % of the inventory have been identified as key categories.

A comparison of the key-category analysis carried out within the CRF Reporter and Germany's key-category analysis has found that the two analyses differ only slightly. Small differences of approach are apparent; for example, Germany divides the energy sector into sub- source categories, while the CRF Reporter differentiates it in accordance with fuel types. The resulting number of key categories is virtually the same in both analyses, however.

1.5.2 Inventory with KP-LULUCF reporting

As a result of the analysis, as described in the previous chapter, of the UNFCCC inventory, CO_2 emissions / removals in the categories *Forest Land* (4.A), *Cropland* (4.B) *Grassland* (4.C) and *Settlements* (4.E) have been identified as key categories. For these categories, additional detailed analyses were carried out, in keeping with the methodological recommendations in Chapter "2.3.6 Choice of method" of the 2013 Revised Supplementary Methods and with the Good Practice Guidance Arising from the Kyoto Protocol. As a result, the sub-categories listed in Table 7 were identified as key categories for the KP-LULUCF inventory pursuant to Article 3.3. The key factors in such selections were the relevant emissions-contribution levels and emissions trends. With the help of Table 2.1.1, the activities selected in accordance with Article 3.4 were then correlated with these categories. Under this article of the Kyoto Protocol, Germany has selected the categories forest management, cropland management and grazing land management. These results, as well as the criteria used for the selection, are presented in CRF Table NIR.3 (Table 371 in Chapter 17.1.4)).

Table 6: Key categories for Germany pursuant to the Tier 1 method

IPCC Source Categories	Activity	Emissions of	Level						Trend		Emissions Base Year	Emissions 2013
			Base Year	Base Year + sinks	LEVEL 1990	1990 + sinks	LEVEL 2013	2013 + sinks	2013	2013 + sinks		
1.A.1.a Public electricity and heat production	All fuels	CO_2	●	●	●	●	●	●	●	●	338,451.0	328,385.1
1.A.1.a Public electricity and heat production	All fuels	CH_4	-	-	-	-	-	-	●	●	172.2	2,230.2
1.A.1.a Public electricity and heat production	All fuels	N_2O	-	-	-	-	●	●	-	-	2,407.5	2,546.3
1.A.1.b Petroleum Refining	All fuels	CO_2	●	●	●	●	●	●	●	●	20,165.6	17,993.6
1.A.1.c Manufacture of Solid Fuels and Other Energy Industries	All fuels	CO_2	●	●	●	●	●	●	●	●	65,289.0	10,267.5
1.A.2.a Manufacturing Industries and Construction: Iron and Steel	All fuels	CO_2	●	●	●	●	●	●	●	●	35,269.3	34,080.9
1.A.2.e Manufacturing Industries and Construction: Food Processing	All fuels	CO_2	-	-	-	-	-	-	●	●	2,015.9	303.8
1.A.2.f Manufacturing Industries and Construction: Non-metallic minerals	All fuels	CO_2	●	●	●	●	●	●	●	●	18,507.4	13,072.8
1.A.2.g Manufacturing Industries and Construction: Other	All fuels	CO_2	●	●	●	●	●	●	●	●	127,691.6	76,160.0
1.A.3.b Transport: Road Transportation	All fuels	CO_2	●	●	●	●	●	●	●	●	151,861.0	151,347.6
1.A.3.b Transport: Road Transportation	All fuels	CH_4	-	-	-	-	-	-	●	●	1,316.8	146.5
1.A.3.c Transport: Railways	All fuels	CO_2	●	●	-	●	-	-	●	●	2,899.5	998.9
1.A.3.d Transport: Domestic navigation	All fuels	CO_2	●	●	●	●	-	-	●	●	3,643.6	1,747.7
1.A.4.a Other Sectors: Commercial/institutional	All fuels	CO_2	●	●	●	●	●	●	●	●	64,198.5	40,557.1
1.A.4.a Other Sectors: Commercial/institutional	All fuels	CH_4	-	-	-	-	-	-	●	●	1,449.4	45.0
1.A.4.b Other Sectors: Residential	All fuels	CO_2	●	●	●	●	●	●	●	●	128,638.2	102,892.4
1.A.4.c Other Sectors: Agriculture/Forestry/Fisheries	All fuels	CO_2	●	●	●	●	●	●	●	●	10,261.5	5,651.5
1.A.5 Other: Include Military fuel use under this category	All fuels	CO_2	●	●	●	●	-	-	●	●	11,791.9	1,039.2
1.B.1 Fugitive Emissions from Fuels	Solid fuels	CH_4	●	●	●	●	●	●	●	●	25,553.4	3,580.2
1.B.2.a Fugitive Emissions from Fuels: Natural gas	Gaseous fuels	CH_4	●	●	●	●	●	●	-	-	9,266.1	7,429.0

IPCC Source Categories	Activity	Emissions of	Level						Trend		Emissions Base Year	Emissions 2013
			Base Year	Base Year + sinks	LEVEL 1990	1990 + sinks	LEVEL 2013	2013 + sinks	2013	2013 + sinks		
2.A.1 Mineral products: Cement Production	Clinker Burning	CO_2	●	●	●	●	●	●	-	-	15,145.8	12,257.8
2.A.2 Mineral Products: Lime Production	burning of Limestone and Dolomite	CO_2	●	●	●	●	●	●	-	-	5,986.6	4,811.3
2.B.1 Chemical Industry	Ammonia production	CO_2	●	●	●	●	●	●	●	●	6,025.0	6,739.0
2.B.2 Chemical Industry	Nitric acid production	N_2O	●	●	●	●	-	-	●	●	3,258.5	480.4
2.B.3 Chemical Industry	Adipic acid production	N_2O	●	●	●	●	-	-	●	●	18,076.7	338.3
2.B.8 Petrochemical and carbon black production	0	CO_2	-	-	-	-	-	-	●	●	886.3	1,980.2
2.B.9 Fluorochemical production		HFC	●	●	●	●	-	-	●	●	5,335.2	46.7
2.C.1 Metal Production: Iron and Steel Production	Steel (integrated production)	CO_2	●	●	●	●	●	●	●	●	22,810.3	13,978.0
2.C.3 Aluminium Production	0	PFC	-	-	-	-	-	-	●	●	1,800.7	107.7
2.F Product uses as substitutes for ODS	0	HFC	-	-	-	-	●	●	●	●	2,580.3	10,514.0
2.G Other product manufacture and use	0	N_2O	-	-	-	-	-	-	●	●	C	C
2.G Other product manufacture and use	0	SF6	●	●	●	●	●	●	●	●	6,072.2	3,107.6
3.A.1 Enteric fermentation	Dairy cattle	CH_4	●	●	●	●	●	●	-	-	19,089.1	14,380.6
3.A.1 Enteric fermentation	Non-dairy cattle	CH_4	●	●	●	●	●	●	●	●	14,163.3	9,176.0
3.B.3 Manure Management	Swine	CH_4	-	●	-	-	-	-	-	-	2,684.7	2,403.0
3.D Agricultural Soils	0	N_2O	●	●	●	●	●	●	●	●	28,292.9	25,278.6
3.G Liming	0	CO_2	-	-	-	-	-	-	●	●	1,276.9	1,956.5
3.J Other	0	CH_4	-	-	-	-	-	-	●	●	0.3	1,115.4
4.A Forest land	0	CO_2		●		●		●		-	-74,537.2	-56,832.2
4.B Cropland	0	CO_2		●		●		●		●	15,474.5	13,671.4
4.C Grassland	0	CO_2		●		●		●		●	20,882.1	22,237.6
4.E Settlements	0	CO_2		-		-		●		●	2,548.9	3,577.8
4.G Harvested Wood Products	0	CO_2		-		-		●		●	-1,360.0	-2,588.0
5.A Solid Waste Disposal on Land	Managed Waste Disposal on Land	CH_4	●	●	●	●	●	●	●	●	33,525.0	9,850.0
5.B Biological treatment of solid waste	0	CH_4	-	-	-	-	-	-	-	●	25.3	737.6
5.B Wastewater Handling	Domestic Wastewater	CH_4	-	-	-	-	-	-	●	●	1,765.7	23.8

Table 7: Results of KP-LULUCF key-category assessment

Category	Gas	1990	2013	2013
4.A.1 Forest Land remaining Forest Land	CO_2	69,435.9	52,269.6	●
4.A.1 Forest Land remaining Forest Land	CH_4	1.8	1.7	-
4.A.1 Forest Land remaining Forest Land	N_2O	0.7	0.8	-
4.A.2 Land converted to Forest Land	CO_2	5,101.3	4,562.6	●
4.B.1 Cropland remaining Cropland	CO2	9,418.8	7,989.9	●
4.B.1 Cropland remaining Cropland	N_2O	IE	IE	IE
4.B.2 Land converted to Cropland	CO_2	6,055.8	5,681.5	●
4.B.2 Land converted to Cropland	N_2O	0.9	1.0	-
4.C.1 Grassland remaining Grassland	CO_2	18,784.3	20,232.6	●
4.C.2 Land converted to Grassland	CO_2	2,097.8	2,005.0	-
4.D.1 Wetlands remaining Wetlands	CO_2	2,421.8	2,459.3	-
4.D.2 Land converted to Wetlands	CO_2	204.7	6.4	-
4.E.1 Settlements remaining Settlements	CO_2	820.6	474.1	-
4.E.2 Land converted to Settlements	CO_2	1,728.3	3,103.7	●
4.F.1 Other Land remaining Other Land	CO_2	0.0	0.0	-
4.F.2 Land converted to Other Land	CO_2	0.0	0.0	-
4.G Harvested wood products	CO_2	1,360.0	2,588.0	●
4.H Other	N_2O	0.4	0.4	-

Table 8: Key categories for Germany identified solely via the Tier 2 approach

IPCC Source Categories	Activity	Emissions of
1.A.4.b Other Sectors: Residential	All fuels	CH_4
3.B.1.a Manure Management: Other	Dairy cattle	N_2O
3.B.5 Indirect N_2O emissions	Atmospheric deposition	N_2O
4.C Grassland		CH_4
4.D Wetlands		CO_2
5.B Wastewater Handling	Domestic Wastewater	N_2O

1.6 Information regarding the quality assurance and quality control plan , the inventory plan (including verification) and management of confidential information

1.6.1 Quality assurance and quality control procedures

1.6.1.1 QC/QA plan

Pursuant to the 2006 IPCC Guidelines, the necessary QC/QA and verification measures for emissions reporting should be summarised in a QC/QA plan. Such a QC/QA plan is to serve the primary purpose of organising, planning and assuring the proper execution of such QC/QA measures. The QC section of the plan is relatively simply structured, and it remains unchanged from year to year. This is in keeping with the National System's basic purpose, which is to subject the entire inventory, each year, to a complete QC process in accordance with the Guidelines, and to cover all categories in the process, regardless of whether they are key categories or not. The QC section of the plan basically consists of the QC/QA checklists (cf. Chapter 1.6.1.2) and the inventory plan (cf. Chapter 1.6.1.3). A nearly identical approach is used with the QA section of the plan. This means that quality checks are carried out each year, as required by the Guidelines. At the same time, the required "peer reviews" are carried out periodically (see also below). The QA section of the plan thus basically consists of the QC/QA checklists (cf. Chapter 1.6.1.2) and of the schedule for emissions reporting (cf. Chapter 1.2.1.5), including the tasks that schedule entails. Those checklists and schedule, along with the approval processes specified by the QSE, ensure that inventories annually undergo numerous checks, including internal checks and (especially) checks carried out by external checking authorities focussed on quality assurance. The external checks also include the "basic expert peer reviews" that are carried out annually by the participating ministries. The results of those reviews, including any required corrections, enter into inventories prior to completion of the reporting process, and in the framework of the established routines. These quality assurance activities are complemented and reinforced by periodic peer reviews (cf. Chapter 1.6.1.4).

Regular adaptation and revision of the aforementioned instruments, also taking country-specific requirements into account, ensure that the requirements of the 2006 Guidelines are met also in terms of proper consideration of specific national circumstances.

A general description of the manner in which the quality assurance and control process is organised – with regard to both establishment and workflow – is provided in Chapter 1.3.3.1. That section also describes the principles by which QC/QA measures are controlled and documented.

The requirements for quality assurance and quality control measures in emissions reporting are described in detail in the "Handbook for quality control and quality assurance in preparation of emissions inventories and reporting under the UN Framework Convention on Climate and EU Decision 525/2013/EC" ("Handbuch zur Qualitätskontrolle und Qualitätssicherung bei der Erstellung von Emissionsinventaren und der Berichterstattung unter der Klimarahmenkonvention der Vereinten Nationen sowie der EU Entscheidung 280/2004/EG" (Federal Environment Agency, 2015, unpublished). The most important specifications set forth in the handbook consist of quality reviews carried out primarily prior to the conclusion of inventory preparation.

1.6.1.2 Checklists

The quality checks are carried out with the help of checklists (for the relevant content, cf. Chapters 1.3.3.1.5 and 22.1.2.1.11). These lists currently comprise some 100 role-specific individual targets and some 50 optional targets.

Currently, some 50 Federal Environment Agency and external staff, in various functional roles, and in four layered, cumulative QC/QA review levels, are involved in emissions reporting. The review levels are represented, in each case, by the relevant expert (Fachverantwortlicher – FV); his superior, the QC/QA section representative (QKV); a specialised contact person, within the Single National Entity, for the relevant category (Fachlicher Ansprechpartner – FAP); and, finally, the co-ordinators responsible for achieving a consistent overall result comprising the NIR, the inventory, the QSE and uncertainties estimates.

In inventory preparation, role-specific QC/QA reviews are linked with general quality targets (cf. Chapter 22.1.2.1.10.3) and individual process steps (cf. Chapter 1.2.3), so that final evaluation can take account of such targets and steps. As a whole, the reviews cover the entire inventory-preparation process.

Subsequent evaluation of the checklists reveals, for specific categories, aspects that need to be reviewed – and, possibly, revised – with regard to fulfillment of specific inventory requirements. Such fulfillment is achieved via addition of pertinent further information. The great majority of all identified review requirements are added to the binding inventory plan. The inventory plan undergoes internal and interdepartmental approval processes and is then published in aggregated form.

1.6.1.3 Inventory plan

For the annual preparation of the inventory plan, the results of the QC/QA checklists for all categories are evaluated, and targets that have not been achieved are assigned improvement measures as necessary, as well as deadlines for their implementation (follow-up procedure). Those measures are then complemented by the improvement activities mentioned in the NIR (cf. Chapter 10.2.1), the results of the various review procedures of the UNFCCC and the EU Commission and by any listings of further required improvements. In a longer time frame, further potential verification activities are outlined (cf. 1.6.1.4). The inventory plan comprises a range of individual measures that are to be implemented by the various roles within the QSE (cf. the role concept within QSE, Chapter 1.3.3.1.3) and by the Federal German ministries involved in emissions reporting (cf. Chapter 1.2.1.4), along with their subordinate authorities. The included measures are binding, i.e. have to be completed within the time periods defined within the inventory plan, although it must be noted that the relevant responsible NaSE participants have to provide the necessary personnel and financial resources for the measures.

During the preparation for each current IP, the QSE coordinator reviews whether the required actions defined in previous years have been completed. The IP is then updated with the information that results from such review. Required actions that could not be completed by the defined deadlines are flagged with an "overdue" status and given higher priority (in the "follow-follow-up procedure").

Because the individual measures included within the inventory plan are so numerous – they are too many to be listed here – they have been combined into overarching measures, as shown in Table 9. The inventory plan is updated at least once a year, via an ongoing process.

As measures within the inventory plan are implemented, large numbers of the included individual measures are processed to the point where they can be removed from the list. This occurs on a regular basis.

Table 9: Inventory plan 2015 – areas in which action is required

Category	CRF	Planning for inventory improvement / required actions	Source	Source-Reference-Year of Reporting
Energy	1.A.1, 1.A.1.c, 1.A.2.f, 1.A.3.e	Check whether the data source (s) used will be available throughout the long term.	CHKL	2014
Waste	5.D.2		CHKL	2015
Industrial Processes	2.A.4.a	Check whether there are any gaps in the available data for time series as of 1990.	CHKL	2013
LULUCF	4		NIR	2015
Energy	1.A.1, 1.A.2.g.viii, 1.A.3.e, 1.D.1.b	Check whether the category is completely covered by the relevant data source and whether the defined data sets for EF and AD are consistently delimited.	CHKL	2014, 2015
Industrial Processes	2.D.3.(c)		CHKL	2012
Waste	5.D.2		CHKL	2015
General	-	Check whether uncertainties have been determined and are complete.	ARR, CHKL	2013, 2015
Energy	1.A.2.g.vii., 1.A.3.b+c+d.(a)+e.ii, 1.A.4.a.ii+b.ii+c.ii+iii, 1.A.5.b		CHKL	2010, 2012, 2014, 2015
Industrial Processes	2.D.3.(b), 2.G.4.(a)		CHKL	2012, 2015
General	-	Check whether obligations pertaining to keeping of records and documentation are fulfilled and whether the relevant documents are complete and meaningful.	CHKL	2015
Energy	1.A, 1.A.2.e, 1.A.3.a.ii, 1.A.3.b+c+d.(a+b)+e.ii, 1.A.4.a.ii+b.ii+c.ii+iii,, 1.A.5.b, 1.D.1.b		CHKL	2011-2015
Industrial Processes	2.B.10.(i)		CHKL	2015
Waste	5.D.1+2		CHKL, Other	2012, 2014, 2015
General	-	Check whether data suppliers and contracted supporting entities are carrying out suitable routine quality controls, and whether the requirements pertaining to emissions reporting, as defined by the Single National Entity, have been provided to such suppliers and entities and are being fulfilled.	CHKL, Other	2014
Energy	1.A.1, 1.A.3.a-c+d.(b), 1.A.4.c.iii, 1.A.5.b		CHKL	2010, 2012, 2014, 2015
Industrial Processes	2.C.2, 2.D.3.(b)		CHKL	2012
Waste	5.D.1		CHKL	2012
General	-	Check whether requirements for cross-checking and verification of data and their underlying assumptions have been fulfilled.	CHKL, Other	2015
Energy	1, 1.A, 1.A.1+b, 1.A.2+a+f, 1.A.4.a.ii+b.ii		ARR, CHKL, Sonstige	2012, 2014, 2015
Industrial Processes	2.A.1, 2.A.4.a, 2.B.4.a+8.a-e+10.(i), 2.D.1+2, 2.G.3.a(i), 2.G.4.(a)+(c)		ARR, CHKL	2013-2015
Agriculture	3.H+J		CHKL	2015
LULUCF	4, 4.(II)-(V), 4.A.(a)+(b), 4.B-G		CHKL, NIR	2012, 2014, 2015
Waste	5.D.1+2		CHKL	2014, 2015
General	-	Check whether it was possible to take pointers from inventory reviews into account.	ARR	2010
Energy	1.A.		ARR	2010
Waste	5.D.1		CHKL	2014

Category	CRF	Planning for inventory improvement / required actions	Source	Source-Reference-Year of Reporting
ETS	-	Check whether data-consistency requirements are fulfilled and whether the relevant documents are complete and meaningful.	ARR	2011
Energy	1, 1.A.2.g.vii, 1.A.3.c, 1.A.3.d.(a), 1.A.4.a.ii+c.ii, 1.A.5.b,		ARR, CHKL	2013, 2015
Industrial Processes	2.B.10.(i), 2.G.4.(a)		CHKL	2015
Waste	5.A.1, 5.D.1+2, 5.E.1		CHKL, NIR	2013-2015
Industrial Processes	2.C.6	Check whether the EF meet requirements for completeness (are without gaps, are fully documented and are plausible).	NIR	2015
LULUCF	4. (Total area)		NIR	2015
Energy	1.A.3.a+b+d, 1.A.4.a.i., 1.D.1.a.+b	Check whether the activity data meet requirements for completeness (are without gaps, are fully documented and are plausible).	NIR	2013, 2015
Industrial Processes	2.B.4.a.		NIR	2015
LULUCF	4.A.		NIR	2012
Waste	5.D.2		ARR, other	2012, 2015
General	-	Check whether data has been entered into the CSE correctly, including whether all numbers, units and conversion factors have been correctly entered and properly integrated.	CHKL	2015
Waste	5.D.1		CHKL	2014, 2015
Industrial Processes	2.B.4.a+8.a-e+10.(i), 2.G.3.a.(i)	Check whether the NIR category has been completely and logically described in terms of the required six sub-chapters for the NIR ("category description", "Methodological issues", etc.).	CHKL	2015
LULUCF	4.G		CHKL	2015
Waste	5.D.1+2		CHKL	2014, 2015
General	-	Various types of required action.	Other	2014
Energy	1.A.2.e, 1.A.3.b+c+d.(a+b)+e.ii , 1.A.4.b.ii+c.ii+c.iii, 1.A.5.b, 1.B.2		CHKL, Other	2013-2015
Industrial Processes	2.B.10.(i), 2.D.3.(c)		CHKL, NIR	2012, 2015
Agriculture	3.A+B+D		NIR	2011, 2012
Waste	5.D.1+2		CHKL, Other	2013, 2015
KP	KP		ARR	2013
Energy	1.A.3.d.(a), 1.A.4.c.iii	Check whether pertinent responsibilities need to be updated.	CHKL	2015
Industrial Processes	2.D.3.(b)	Initiated research projects for inventory improvement.	NIR	2012
LULUCF	4.A-C		NIR	2011, 2012

The first inventory plan was published together with the 2007 Submission. Since then, several thousand items for action or improvement have been addressed within the quality system. Since that total is too unwieldy to be presented in any clear manner, we simply provide an overview of the development of the IP since the 2010 Submission.

As of the end of the current reporting year, the inventory plan comprises some 1,520 items for action or improvement. Of those items, which are distributed throughout about 160 categories, some 1,200 (last year: 1,000) have been completed.

In the current round of reporting, some 160 new required improvements have been identified. Here it should be noted that the review results of 2014 were not transmitted until after 15 April 2015 (on 28 April 2015) and thus could not be included in the IP. At the same time, an additional 30 of the review results (required actions) from previous years were addressed and fully processed in this year's reporting round. The focuses of all improvements completed to date include the areas of review results, documentation and verification. The focuses of the some 250 required improvements (last year: about 230) that are still open or still undergoing processing include verification, documentation and uncertainties. If one takes into account the number of repetitions that necessarily result via recurrence of checklist and review results of past years, then the number of open improvement items decreases to an actual figure of about 340.

The overview in Table 10 presents more-detailed information on the improvement items that have been successfully addressed. Both tables (Table 9 & Table 10) include the review results from the years 2006 through 2013, the statements made in the NIR relative to planned improvements in the years as of 2011, the other improvement items for the years as of 2008 and the CHKL results from the years as of 2010.

Detailed information regarding individual improvements, with respect to categories, priorities, deadlines, responsibilities, gases, fuels, needs for action, etc., cannot be provided here, due to the sheer scope of the information involved. With regard to successfully addressed Review results, more-detailed excerpts from the inventory plan are provided in Table 340 (Compilation of the Review recommendations successfully addressed as of the current report), while information relative to statements made in the NIR regarding planned improvements is provided in Table 341 (Compilation of a) the planned improvements completed as of the present report and of b) the planned improvements that are mentioned in NIR category chapters and are still pending).

Table 10: Inventory plan – Items for action/improvement that have been successfully addressed

Category	CRF	Planning for inventory improvement / required actions	Source	Source-Reference-Year of Reporting
Energy	1.A, 1.A.4.c.iii., 1.D.1.b.	Check whether requirements of IPCC Good Practice Guidance pertaining to selection of calculation method and to procedures for any methods changes are fulfilled, or whether existing calculation methods / models need to be adjusted.	ARR, CHKL	2008, 2011-2014
Industrial Processe s	2.A., 2.B.8, 2.C., 2.C.1, 2.E., 2.F.1+6		S&A I, NIR, CHKL	2006, 2010, 2012
Agricultur e	3.A+B		NIR, ARR, other	2009, 2011-2013
LULUCF	4.D			
Waste	5.A, 5.D.1		ARR, CHKL	2011-2014
Energy	1.A.2	Check whether the data source (s) used will be available throughout the long term.	CHKL	2011
Agricultur e	3.A.(a), 3.B.(a)		CHKL	2010
LULUCF	4		Other	2008
Waste	5.E.1		CHKL	2010
Energy	1.A.3.c	Check whether there are any gaps in the available data for time series as of 1990.	CHKL	2010, 2013+2014
Industrial Processe s	2.C.2+3		CHKL	2010-2011
Agricultur e	3.A.(b), 3.B.(b), 3.D		CHKL	2010-2011
LULUCF	4.A.(a)		CHKL	2012
Waste	5.D.2		NIR	2013
Energy	1.A.3.e.ii, 1.A.4.c.ii	Check whether the category is completely covered by the relevant data source and whether the defined data sets for EF and AD are consistently delimited.	CHKL	2011, 2014
Waste	5.A.1, 5.D.1		CHKL, NIR	2011, 2012

Category	CRF	Planning for inventory improvement / required actions	Source	Source-Reference-Year of Reporting
General	General	Check whether uncertainties have been determined and are complete.	ARR	2011
Energy	1.A.2, 1.A.3.a.ii, 1.A.3.b+c, 1.A.3.e.ii, 1.A.5.b		CHKL	2010-2012, 2014
Industrial Processes	2.C.1-3, 2.D.3.c		CHKL, NIR	2010-2011
LULUCF	4, 4(III+IV), 4.A, 4.B-F		Other, CHKL, NIR, ARR	2008, 2010-2011
Waste	5.A.1, 5.D.1		CHKL	2010-2014
Energy	1.A, 1.A.1+2, 1.A.3.a-e, 1.A.4, 1.A.4.c.ii+iii, 1.A.5.a+b, 1.B.1+2, 1.D.1.b	Check whether obligations pertaining to keeping of records and documentation are fulfilled and whether the relevant documents are complete and meaningful.	CHKL, ARR	2010-2015
Industrial Processes	2.C.1-3, 2.G.3.a.(i)+b, 2.H.1+2		CHKL	2010-2011, 2014
Agriculture	3.A.(a), 3.B.(a)		CHKL	2010
LULUCF	4, 4(III+IV), 4.A-F		CHKL, Other	2008, 2010
Waste	5.A.1, 5.B.1, 5.D.1, 5.E.1		CHKL	2010-2012
General	General	Check whether data suppliers and contracted supporting entities are carrying out suitable routine quality controls, and whether the requirements pertaining to emissions reporting, as defined by the Single National Entity, have been provided to such suppliers and entities and are being fulfilled.	CHKL	2014
Energy	1.A.2, 1.A.3.a.ii, 1.A.3.b-d, 1.A.3.e.ii, 1.A.4.c.ii, 1.A.5.b, 1.D.1.b		CHKL	2010-2011, 2014
Industrial Processes	2.C.2		CHKL	2011
Agriculture	3, 3.A., 3.B., 3.D		CHKL, Other	2008, 2010-2011
LULUCF	4, 4(III), 4.A.1, 4.B-F		CHKL, Other	2008, 2010, 2012
Waste	5.D.1		CHKL	2010-2011
General	General	Check whether requirements for cross-checking and verification of data and their underlying assumptions have been fulfilled.	ARR	2008
Energy	1, 1.A, 1.A.1+2, 1.A.3.a-e, 1.A.4, 1.A.4.c.ii+iii, 1.A.5.a+b, 1.B.1+2, 1.D.1.a		ARR, Eu-Rev, S&A I, CHKL, NIR	2006-2008, 2010-2014
Industrial Processes	2.A.1-4, 2.B.1+7+8.a., 2.C.1-3, 2.D.3.(b), 2.H.2		ARR, CHKL, NIR	2010-2014
LULUCF	4(III), 4.B-F		CHKL, NIR	2010, 2012, 2014
Waste	5.A.1, 5.D		CHKL	2010-2013
General	General	Check whether it was possible to take pointers from inventory reviews and from the inventory plan into account.	ARR, IRR	2006, 2008-2013
Energy	1, 1.A, 1.A.1.a+b, 1.A.2, 1.A.2.a+f, 1.A.3.b-d, 1.B.1+2, 1.D.1		ARR, IRR, SL	2006, 2008-2013
Industrial Processes	2, 2.A.1+2, 2.A.4.b+d., 2.B.1-3+9, 2.C.1-4, 2.D.3.(a), 2.F+G		ARR, IRR, CHKL	2006, 2008-2010, 2012-2013
Agriculture	3, 3.A-D		ARR, IRR, NIR	2006, 2008-2010, 2012-2013
LULUCF	4, 4.A-D		ARR, IRR, SL	2006, 2008-2010, 2012-2013
Waste	5, 5.A, 5.C.1, 5.D, 5.E		ARR, IRR	2006, 2008-2010, 2012-2013
KP	Kyoto Protocol		ARR	2010-2013

Category	CRF	Planning for inventory improvement / required actions	Source	Source-Reference-Year of Reporting
General	General	Check whether data-consistency requirements are fulfilled and whether the relevant documents are complete and meaningful.	ARR	2011
Energy	1.A, 1.A.1+2, 1.A.2.a+f, 1.A.3.a.ii+b+d, 1.A.4, 1.B.1.a, 1.B.2		ARR, EU-Rev, S&A I, CHKL, NIR	2006-2008, 2010-2014
Industrial Processes	2, 2.A.4.d, 2.B.2+8, 2.C.1, 2.D.3.(b+c), 2.F.1, 2.H.1.(b)		ARR, EU-Rev, CHKL	2007, 2010-2013
Agriculture	3, 3.D		ARR	2008
LULUCF	4, 4.A.2, 4.B.1, 4.C.1		EU-Rev, NIR	2007, 2013
Waste	5.A, 5.D		ARR, EU-Rev, CHKL, NIR	2007, 2011-2013
Energy	1.A.1, 1.A.2, 1.A.3.d(b)+e.ii, 1.A.4, 1.A.5.a	Check whether the EF meet requirements for completeness (are without gaps, are fully documented and are plausible).	ARR, CHKL, EU-Rev, S&A I, NIR	2006, 2007, 2011-2014
Industrial Processes	2.B.1, 2.C.4, 2.F		EU-Rev, NIR	2007, 2011
Agriculture	3.B, 3.B.(b)		EU-Rev, NIR	2007, 2012
LULUCF	4.C.2		EU-Rev	2007
Waste	5.B.1, 5.D.1		CHKL, NIR	2013+2014
General	General	Check whether the activity data meet requirements for completeness (are without gaps, are fully documented and are plausible).	Other	2008
Energy	1.A.1; 1.A.2; 1.A.4; 1.A.5.a, 1.B.1.c		EU-Rev, S&A I, NIR, CHKL	2006, 2007, 2011-2013
Industrial Processes	2.A.3		NIR	2011-2012
Agriculture	3.A(b)+B+D		NIR	2011-2012
LULUCF	4.A-C		NIR	2011-2012
Waste	5.A.1, 5.D.2, 5.E.1		ARR, NIR	2011-2013
Waste	5.D.1	Check whether data has been entered into the CSE correctly, including whether all numbers, units and conversion factors have been correctly entered and properly integrated.	CHKL	2011
General	General	Check whether the NIR category has been completely and logically described in terms of the required six sub-chapters for the NIR ("category description", "Methodological issues", etc.).	ARR	2011
Energy	1, 1.A., 1.A.1, 1.A.2.f.(a-d), 1.B.1, 1.B.2.a		ARR, CHKL	2008, 2011-2013
Industrial Processes	2.A.4(a), 2.B.1+9, 2.C, 2.C.2+3, 2.D.3.(b), 2.H.1.(a)		ARR, EU-Rev, CHKL	2007, 2010-2011-2013
LULUCF	4, 4.A.(b)		ARR, CHKL	2011, 2014
Waste	5.C.1, 5.D		ARR, CHKL	2011-2013
General	General	Check whether recalculations need to be carried out. If so, then the recalculations have to be clearly and logically documented.	ARR	2011
Energy	1, 1.A.1+2+4		EU-Rev, S&A I	2006, 2007
Industrial Processes	2		ARR, EU-Rev, S&A I	2006, 2007, 2011-2013
Agriculture	3		S&A I	2006
LULUCF	4.A		ARR	2011
Waste	5, 5.E		S&A I, EU-Rev	2006, 2007

Category	CRF	Planning for inventory improvement / required actions	Source	Source-Reference-Year of Reporting
General	General	Various types of required action.	ARR, other	2010+2011, 2013+2014
Energy	1.A., 1.A.2.f.(a-d), 1.A.3.a+b+d+e, 1.A.4.+a.ii+c.ii, 1.A.5.b, 1.B.1, 1.B.2.d		NIR, other, CHKL	2009-2014
Industrial Processe s	2.A.4.d., 2.C.1, 2.D.3.(a+c), 2.G.3.a.(i), 2.G.3.b., 2.G.4, 2.H.1.		ARR, CHKL, NIR	2010-2013
Agricultur e	3		NIR	2011
LULUCF	4, 4.A-D		ARR, NIR	2008, 2011, 2013
Waste	5.D		Other	2013
Energy	1.A.2.b+d+e, 1.A.3.e., 1.B.1, 1.B.2.b, 1.B.2.c.iii.-Flaring	Check whether pertinent responsibilities need to be updated.	CHKL	2010, 2013+2014
Industrial Processe s	2.A.4.(b), 2.B.8.a-c+g.(i), 2.D.3.(b+c), 2.G.3.a.(i), 2.G.3.b, 2.H.1.		CHKL	2010-2014
Waste	5.D.1		CHKL	2010, 2013
Energy	1.A.1, 1.A.2.f, 1.A.3.c-e, 1.A.4.c.iii., 1.B.1.c, 1.B.2, 1.D.1.b.	Initiated research projects for inventory improvement.	CHKL, NIR	2011-2014
Industrial Processe s	2.A.2, 2.G.2		NIR	2011+2012
Agricultur e	3.B		NIR	2012
LULUCF	4.A+E		NIR	2011-2012
Waste	5.A.1, 5.B.1		CHKL, NIR	2011-2012, 2014

1.6.1.4 Workshop on the National System (Peer Review)

In November 2004, the Federal Environment Agency held a first workshop on the National System of Emissions Inventories. This created a forum that significantly promoted inclusion of associations and other independent organisations, as well as supporting implementation of Paragraph 15 (b) of the *Guidelines for National Systems*, which requires that inventories be reviewed by third parties (peer review).

In May 2009, a second workshop on the National System was held, with the purpose of facilitating another review of the inventories by independent third parties, pursuant to Paragraph 15 (b) of the *Guidelines for National Systems*. That second workshop focussed on specific categories within the inventory. The selected areas included "N_2O from product use", "emissions from non-energy-related use of fossil fuels" and "SF_6 emissions from the photovoltaics industry". The persons invited to the discussion of inventory areas included experts from the various sectors, industry representatives and independent experts. For example, with regard to the area of use of N_2O, the invited participants included sellers of industrial gases, and representatives of the Berufsverband deutscher Anästhesisten (BDA; Professional Association of German Anaesthetists) and of the Federal Institute for Materials Research and Testing (BAM). With regard to the area of non-energy-related uses, discussions were held with representatives of the Association of the German Chemical Industry (VCI) and of affected chemical producers. Participants with a focus on photovoltaics production included representatives of producers, industrial-gas sellers, systems builders, universities and research establishments. The topics were comprehensively and intensively discussed. The workshop contributed significantly to overall improvement of the data and of the quality of reporting.

In May 2011, an international experts' workshop on the German LULUCF-reporting system took place. That workshop reviewed the methodological changes made as a result of the In-Country Review of September 2010. All of the recommendations made by experts in that framework have been fully implemented.

In April 2012, a discussion was held with the Federal Statistical Office regarding the topic of natural gas statistics. The participants in the technical discussion included representatives of the Federal Statistical Office, the Federal Environment Agency (UBA) and of the German Association of Energy and Water Industries (BDEW), as well as representatives of various gas companies and the German Institute for Economic Research (DIW; Working Group on Energy Balances (AGEB)). In preparation for revision of the national Energy Balance, the discussion focussed on the available natural gas statistics. In the process, measures were approved that will directly improve the Energy Balance and, thus, will improve the emissions inventory. In addition, agreement was reached on additional study that will be carried out in order to verify the available statistical data.

1.6.1.5 Cross-Country Review on fluorinated gases

In February 2011, a group of experts met in Vienna for a cross-country review focussing on reporting on F gases. The participating countries included the UK, Austria and Germany. After basic presentations of data collection in the three countries, the various individual areas of application concerned were considered in detail and compared in terms of data sources, precision, emission factors and other criteria. In the process, it emerged that, of the three countries, Germany has the most extensive specialised knowledge resources and presumably is thus best able to assess the completeness and plausibility of the available data.

One of the key results that emerged from the cross-country review is that all three countries have to commit high levels of manpower to reporting on F gases. Any reduction in such resources commitments would mean that reporting would no longer be IPCC-conformal.

As a result of the meeting, a report was prepared that has entered into German reporting regarding F gases.

1.6.2 Activities for verification

1.6.2.1 Verification in selected categories

In the 2015 reporting year, a verification project was carried out, in keeping with the *2006 IPCC Guidelines (Vol.1, Chapter 6)*. In the project, all of the inventory's categories were reviewed for any need for verification. The following categories were identified:

- 1.A.2.a Iron & Steel
- 1.A.3.e Other Transportation
- 1.B.1.a.ii Surface Mining
- 1.B.2.b.v.i Natural Gas: Other
- 2.A Mineral Industry
- 2.B.1 Ammonia Production
- 2.B.2 Nitric Acid Production

- 2.B.3 Adipic Acid Production
- 3 Agriculture
- 4 Land Use Matrix
- 4 Consistency between the descriptions in the NIR and the CRF tables
- 4.A Forest Land
- 5.A.1 Managed Waste Disposal

For each of the listed categories, verification has been, or will be, carried out by the project holder. Upon completion of this work, the results will be listed in the relevant categories' verification chapters (i.e. the results for a given category will be listed in that category's verification chapter). The project has not yet been completed. For this reason, some of the results will have to be published in subsequent reports.

1.6.2.2 Procedure for using monitoring data from European emissions trading

In efforts to fulfil mandatory quality criteria, a need has been seen – especially within the EU – to use data from the EU Emissions Trading Scheme (EU ETS) to improve greenhouse-gas emissions inventories. All Member States are now called upon to use ETS data to improve the quality of their annual national emissions inventories.

A reliable database from emissions trading, showing relevant annual emissions, is available for the period since ETS monitoring commenced. Those data can be used, in aggregated form, to draw category-specific conclusions regarding the completeness and consistency of certain parts of emissions inventories. In addition, they provide a basis for reviewing emission factors used and for verifying activity data. Since emissions calculations for all components are all based on the same activity data, such verification is of significance for all reported emissions inventories.

Emissions-trading data required for improvement of inventory data subject to reporting are available in electronic form, in the installations database of the German Emissions Trading Authority (DEHSt). In 2005, agreement was reached regarding a general procedure for individual data queries related to inventory preparation. In the main, this procedure involves direct communication between the Single National Entity and the German Emissions Trading Authority's section E 2.3, which is responsible for reports (cf. Chapter 1.3.3.1.8). To make it possible to use this "resource" on a regular basis, this formalised procedure for the pertinent required annual data exchanges, including deadlines and defined workflows, has been agreed.

Monitoring data from European emissions trading will be used to improve the quality of annual national emissions inventories with respect to categories that include installations subject to reporting obligations under the CO_2 Emissions Trading Scheme (ETS). Relevant information is provided in the category chapters on verification, although the detailed comparisons involved are presented only in some cases. For reasons of confidentiality, especially regarding certain inventory details, the results of the comparisons are usually simply described in text form. Tables with the data used can be made available only in connection with inventory reviews. The comparison of fuel-related CO_2 emission factors in the Annex, Chapter 18.7, provides a sample overview of a successful verification.

In several cases, the DEHSt's data provision to responsible experts for the inventory had to be facilitated through project-based support, because person-based confidentiality obligations are easier to implement with such support than they are when staff of the Federal Environment Agency are involved. In a research project (ÖKO-INSTITUT, 2006b), allocation rules were developed that make it possible to compare data from verified emissions reports with data from the inventories' database, on a year-by-year basis. The comparisons, which have been carried out only once to date, have confirmed, in principle, the usefulness of such comparisons for verifying individual categories and identifying data gaps. A follow-on project begun in 2011, "D.E.N.K.", studied whether the allocation rules can be improved and the relevant procedure can be further automated. In the process, it became clear that the data quantities the ETS provides for inventory calculations present challenges in terms of available resources and time. When discrepancies occur in existing aggregates that fulfill requirements for confidentiality of business and operational secrets, the underlying data sets for individual operational steps have to be checked. At an international workshop held within the project framework, experts of other countries confirmed that issue's importance for the German situation. The number of ETS data sets is so large – 35,000 – that the limits of capacities for checking such sets (instead of automatically using the pertinent aggregates) are being reached. Consequently, it will not be possible to bring the procedure used in this area into line with the procedures used in other countries.

1.6.3 Handling of confidential information

When the Federal Statistical Office began providing data in connection with the entry into force of the 3rd SME Relief Act (Mittelstandsentlastungsgesetz 3; MEG 3), the Federal Environment Agency received access to data subject to statistical secrecy.

In addition, from associations and companies, the Single National Entity receives activity data, emission factors and emissions data that reflect operational and business secrets and that are otherwise confidential.

In storing and using such data, therefore, the Single National Entity must take special precautions, and apply special procedures, to protect the confidentiality of the data.

In particular, it must provide for strict separation (both spatial and in terms of staff assignments) of statistical work / analysis and any enforcement of legal provisions pertaining to the installations for which data are collected.

The Single National Entity and the affected sections of the Federal Environment Agency have taken various measures for the purpose of fulfilling these requirements. For example, as a basic rule, persons charged with enforcement of laws in a specific area are never permitted to carry out specialised tasks relative to emissions reporting in the same area.

In 2008, the Single National Entity commissioned a legal study with the aim of precisely assessing the requirements and possibilities pertaining to use and management of data for emissions reporting. The results entered into revision and refinement of the Single National Entity's concept for handling confidential data.

Previously, access to the Central System on Emissions (CSE) database was already limited to a specified group of authorised persons. That measure represents the key precaution for dealing with confidential data. In particular, it makes it practicable to separate – in terms of the persons involved – the tasks of data analysis and legal control. In addition, in 2009 a special access-restricted area was set up, on a central server of the Federal Environment Agency, for confidential electronic data that are not centrally stored in the CSE (for example, energy data subject to statistical confidentiality, emissions-control declarations, data relative to large combustion plants, information about production processes, etc.).

Furthermore, data provided by the *Federal Statistical Office* are placed on a password-/access-protected server (i.e. available only for specifically authorised persons) at the *Federal Statistical Office*.

1.7 General estimation of uncertainties

1.7.1 Greenhouse-gas inventory

The 2006 IPCC Guidelines characterise determination of uncertainties as a key element of any complete inventory. As a result of the need to continually improve the inventories, uncertainties in the inventories play an important role. Uncertainties information is used primarily as an aid for improving the precision of inventories, as well as for selecting methods and carrying out recalculations for inventories. The declared aim is to minimise uncertainties to the greatest possible degree, in order to maximise the inventories' accuracy. Annex I countries must thus first quantify the uncertainties for all categories and sinks, in order to enhance their assessment of inventory quality – which assessment, in turn, is the key to effective inventory planning.

Uncertainties are quantified for emission factors and activity data; in some cases, they are also quantified for emissions.

In general, two methods for determining uncertainties are differentiated. The Tier 1 method combines, in a simple way, the uncertainties in activity data and emission factors, for each category and greenhouse gas, and then aggregates these uncertainties, for all categories and greenhouse-gas components, to obtain the total uncertainty for the inventory. The Tier 2 method for uncertainties determination is the same, in principle, but it also considers the distribution function for uncertainties and carries out aggregation using Monte Carlo simulation. In the Tier 2 method, this process also necessarily includes determining a probability density function for both parameters. Ideally, these functions can be determined via statistical evaluation of individual data items (such as measurements for a large number of facilities). In many cases, few relevant values are available, however, and thus the uncertainty must be determined on the basis of experts' assessments.

Research project 202 42 266 (UBA, 2004) has determined uncertainties, for the first time, in keeping with the Tier 1 and Tier 2 methods, pursuant to Chapter 6 of the 2000 Good Practice Guidance. Since then, the resulting database has been continually improved, and the uncertainties data for the greenhouse-gas inventory have been further improved for the 2015 report. In the current NIR, Germany reports uncertainties that have been calculated pursuant to the Tier 1 method. The uncertainties for the activity data, emission factors and emissions data used were taken from the CSE database. They are based on estimates of experts in relevant departments of the Federal Environment Agency and at external institutions. In cases in which uncertainties information is not yet available in complete form, as an expert's estimate, pertinent figures are added from other sources (such as relevant technical literature). Germany carries out Tier 2 uncertainties analysis every 3 years.

1.7.1.1 Tier 1 approach for uncertainties determination

In the Tier 1 method, in keeping with Chapter 3 of the 2006 IPCC Guidelines, uncertainties are determined on the basis of the uncertainties for AR (activity data), EF and EM, as determined on the lowest sub-category level (primarily by responsible experts of the Federal Environment Agency), and as listed in the CSE. Where asymmetric uncertainties figures are yielded, the larger of the two relevant values is used, under the assumption of a normal distribution, as both the upper boundary and the lower boundary. In each sector, the uncertainties for the individual time series are aggregated to form a total uncertainty for the sector pursuant to the IPCC Good Practice Guidance.

1.7.1.2 Results of uncertainties assessment

In general, uncertainties for activity data can be assumed to be smaller than those for emission factors. In particular, the uncertainties are smaller for activity data derived from fuel use and based on the Federal Energy Balance. On the other hand, uncertainties for activity data derived from disaggregated fuel use normally increase as the relevant disaggregation increases.

- Pursuant to the results from an R&D project (Rentz et al, 2002), the uncertainties in emission factors for indirect greenhouse gases in stationary combustion systems (CRF 1.A.1) are relatively small, as a result of regular monitoring of such emissions. Higher uncertainties are listed for N2 emission factors, since N2 emissions are not normally monitored. The same applies to the emission factors for CH4.
- The uncertainties in the Transport category (primarily CRF 1.A.3) can generally be considered to be small, since precise relevant data on fuel use and vehicle fleets are available, due to taxation obligations, and since that category's emission factors have been very finely modelled and are normally determined via measurements. Some uncertainties may arise via systematic measuring errors or wrong disaggregation.
- In the category Fugitive emissions from fuels (CRF 1.B), the uncertainties for the activity data for oil and natural gas (CRF 1.B.2) are low, as a result of the fuels' being subject to taxation. Flaring of natural gas represents the only exception. The activity data for Coal mining (CRF 1.B.1) are also well-represented by production volumes. By contrast, the uncertainties for emission factors for fugitive emissions are likely to be higher. On the one hand, this results from the many different technical factors that affect fugitive emissions in transport, storage and processing of oil and natural gas. On the other hand, fugitive CH4 emissions from coal mining have thus far been taken into account only as lump sums.
- Considerable uncertainties are seen in many areas in the category of industrial processes (CRF 2). Activity rates based on production figures that must be reported to the Federal Statistical Office can be subject to uncertainties, especially as a result of discrepancies between reporting structures and relevant industry definitions. Activity rates determined from association information are subject to uncertainties that correlate, in each case, with the degree to which the relevant industrial sector is represented in the association in question. For emission factors, uncertainties – which can be considerable, depending on the greenhouse gas in question – result, understandably, from the factors' strong dependence on technology, in combination with extensive technological diversification. Furthermore, equipment-specific emission factors often are tied to business secrets, particularly in sectors with few market players (for example, manufacturing of chemical products (CRF 2.B)), and this tends to make operators hesitant to publish such data or leads them to provide information in consolidated form. In addition, uncertainties can be higher for complex processes in which non-combustion-related activities generate emissions, if relevant emissions-generating processes are inadequately understood and the relevant contributions of pertinent individual activities are not known.

- In the area of production of alcoholic beverages, within the area of Food and drink production (CRF 2.D.2), the activity-rate uncertainties must be considered very small, since production of such beverages is subject to taxation regulations that require very precise determination of production volumes. On the other hand, statistics for sectors with large numbers of small and medium-sized enterprises (such as baked-goods production) tend to be significantly less precise, and thus the activity data for such sectors are subject to higher uncertainties. The uncertainties for the relevant emission factors are also larger, due to the sectors' extensive technological diversification.
- The uncertainties for emissions parameters for the categories Managed waste disposal in landfills (CRF 6.A.1, 6.D) and Industrial wastewater treatment (CRF 6.B.1) are presumed to be high. This applies especially to the areas of composting, MBT and waste landfilling, which have high waste-type diversity that tends to reduce the reliability of data for the relevant emissions parameters. The reasons for the higher uncertainties seen for activity data include the fact that the underlying statistical data make use of non-standardised waste and recycling definitions. The general assumptions relative to the uncertainties of activity data also apply to thermal treatment of waste.

Pursuant to Tier 1, the inventory's total uncertainty figures for 2013 are 5.9 % (level) and 4.9 % (trend). CO_2 sinks and sources in the LULUCF sector make significant contributions to the total uncertainty.

Nitrous oxide emissions overall also play a significant role in the total uncertainty. This effect is shaped especially by nitrous oxide emissions from agricultural soils (3.D), from municipal wastewater treatment (5 D.1) and from manure management (3.B.10).

The CO_2 emissions of the sector Combustion of fuels (1.A) contribute another important share of the total uncertainty. The predominating components of that share include solid fuels in the sector Public electricity and heat production (1.A.1.a) and mobile sources (1.A.3), especially road transports (1.A.3.b) and combustion in the residential, commercial and institutional sectors (1.A.4.a/b/c).

Methane emissions from animal husbandry (3.C Enteric fermentation) and from waste storage (6.A) also make considerable contributions to the total uncertainty. Detailed information about the applicable uncertainties is provided in Annex 7 (cf. Chapter 23).

1.7.2 KP LULUCF inventory

Since the same data and methods are used, under both UNFCCC and KP, for reporting for categories 4.A-4.G, the uncertainties for the two reporting areas are comparable. The information provided in the previous chapter and in the relevant category chapters (cf. Chapters 11.3.1.5 and 19.4.4) applies.

1.8 General checking of completeness

1.8.1 Greenhouse-gas inventory

Completeness information for the various individual categories is presented in CRF Tables 9(a) und 9(b), which, in turn, are summarised in NIR Chapter 21 (Table 430 and Table 431). The following are differentiated in Germany:

- Source-specific emissions and sinks that do not occur (NO – not occurring),

- Source-specific emissions and sinks that are not estimated in Germany, either because they are not quantitatively relevant or because the necessary data for estimates are lacking (NE – not estimated), and
- Source-specific emissions and sinks that are completely accounted for, pursuant to the latest scientific findings, for Germany (All or Full), or that are partly accounted for (Part).

The following section touches on a few category-specific approaches for improving the completeness of the inventory.

All combustion-related activities (1 A) from the area of energy are recorded in full. At certain points, the Energy Balance of the Federal Republic of Germany is supplemented if it is evident that complete coverage is not achieved in selected sub-sections (such as the non-commercial use of wood, secondary fuels). In some categories, separation of combustion-related and non-combustion-related emissions from industry requires further verification. In general, avoidance of duplicate counting is an important part of quality assurance for such categories, however.

In the area of industrial processes, some use is made of production data from association statistics and of manufacturers' information. In the interest of the inventory's completeness and reliability, where emissions reporting is based on such sources, checking of category definitions and data-collection methods will continue to receive priority.

The "Not Estimated" (NE) emissions, which are still reported, consist primarily of non-calculated emissions that, pursuant to IPCC GPG (2003, p.1.11), do not have to be calculated by a reporting country, since those emissions are listed in Appendices 3a.2, 3a.3 and 3a.4..

Some of the emissions data available to the Federal Environment Agency are confidential, due to data-protection requirements, and thus are reported only in aggregated form – although they are reported completely.

An agreement covering provision of data to the Single National Entity by the German Emissions Trading Authority (DEHSt) has been concluded in order to assure the regular exchange of data.

1.8.2 KP LULUCF inventory

Since, for reporting for categories 5.A-5.G, the data and methods used for reporting under UNFCCC do not differ from those used for reporting under KP, the information provided in the previous chapter applies.

2 TRENDS IN GREENHOUSE GAS EMISSIONS

Table 11 below shows the total emissions, as determined for this inventory, of direct and indirect greenhouse gases and of the acid precursor SO_2. Table 12 shows the annual progress achieved, with respect to 1990, for each pertinent year. With the exception of HFCs, significant reductions in emissions have been achieved for all the emissions calculated here. In total, greenhouse-gas emissions, calculated as CO_2 equivalents, decreased by 24.0 % compared to the aforementioned reference figure.

All detailed tables relative to discussion of trends are presented in Annex Chapter 22.3.

Trends, taking account of changes with respect to the previous year of the reporting period

With regard to the previous year, 2012, total emissions rose slightly, by 2.4 %. This resulted from an increase of CO_2 emissions that was due to increased coal consumption for electricity generation, as well as to higher heating requirements in the areas Residential & Commercial and Institutional.

Table 11: Emissions of direct and indirect greenhouse gases and SO_2 in Germany since 1990

Emissions Trends (kt)	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013
Net CO_2 emissions/removals	1,016,520	902,060	858,304	852,040	863,457	836,766	832,524	768,407	813,702	793,809	800,397	823,125
CO_2 emissions (without LULUCF)	1,050,885	938,024	899,386	865,931	877,971	850,861	854,061	789,107	833,112	812,665	817,913	840,605
CH_4	4,790	4,212	3,598	2,827	2,669	2,570	2,538	2,449	2,414	2,371	2,403	2,379
N_2O	221	207	147	148	147	153	155	152	125	129	127	128
HFC (CO_2 equivalent, 1995 base year)		8,354	8,020	9,581	9,784	9,885	10,081	10,660	10,242	10,485	10,710	10,742
PFC (CO_2 equivalent, 1995 base year)		2,086	956	837	668	586	565	405	344	277	241	257
SF_6 (CO_2 equivalent, 1995 base year)		6,467	4,072	3,320	3,242	3,181	2,971	2,924	3,047	3,163	3,155	3,261
NF_3		5	9	34	28	12	30	29	61	61	35	17
NO_X	2,886	2,168	1,928	1,574	1,558	1,484	1,411	1,311	1,333	1,309	1,268	1,267
SO_2	5,307	1,704	645	472	478	461	462	412	434	431	417	416
NMVOC	3,392	2,026	1,599	1,340	1,325	1,265	1,216	1,130	1,238	1,168	1,136	1,138
CO	12,582	6,447	4,816	3,737	3,672	3,590	3,512	3,099	3,544	3,462	3,063	3,089

Table 12: Changes in emissions of direct and indirect greenhouse gases and SO_2 in Germany, since the relevant reference years

Emissions Trends Changes compared to base year / prev. year (%)	Base Year	Base Year to 2012	Base Year to 2013	compared to prev. year (2012 – 2013)
Net CO_2 emissions/removals	*1990*	-21.3	-19.0	+2.8
CO_2 emissions (without LULUCF)	*1990*	-22.2	-20.0	+2.8
CH_4	*1990*	-49.8	-50.3	-1.0
N_2O	*1990*	-42.7	-42.1	+1.0
HFC	*1995*	+28.2	+28.6	+0.3
PFC	*1995*	-88.5	-87.7	+6.7
SF_6	*1995*	-51.2	-49.6	+3.4
NF_3	*1995*	+565.6	+216.1	-52.5
Total Emissons compared to EU Burden Sharing [20]	**fixed Base Year**	**-25.8**	**-24.0**	**+2.4**
NO_X	*1990*	-56.0	-56.1	-0.1
SO_2	*1990*	-92.2	-92.2	-0.1
NMVOC	*1990*	-66.5	-66.5	+0.2
CO	*1990*	-75.7	-75.4	+0.8

[20] Established base-year emissions of 1,232,430 Gg CO_2 equivalent, not including CO_2 from LULUCF. Cf. Chapter 0.2

2.1 Description and interpretation of trends in aggregated greenhouse-gas emissions

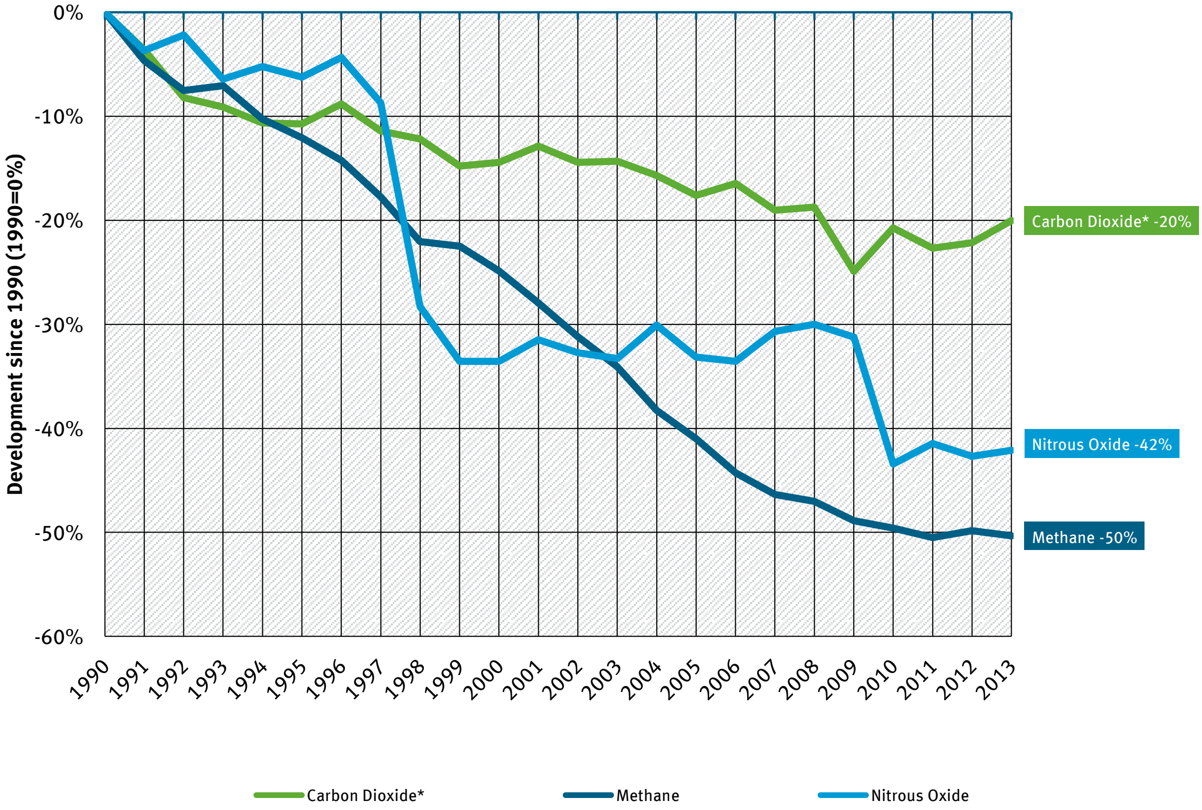
From 1990 through 2013, greenhouse-gas emissions were reduced considerably, by 24.0 %. The individual greenhouse gases contributed to this development to varying degrees (cf. Table 1). Among the direct greenhouse gases, emissions of those gases that predominate in terms of quantity were markedly reduced, with the strongest reductions occurring for methane. The main reasons for these developments are found in the following areas:

- Transition from use of solid fuels to use of liquid and gaseous fuels, which have lower emissions, in the period since 1990;
- Growing use of renewable energies, and growing, related, use of substitutes for fossil fuels;
- Increased plant (installation) efficiencies;
- Changes in animal-housing methods, and reductions of livestock populations;
- Fulfillment of legal regulations in the waste-management sector;

Such areas are considered in greater detail in the discussion below of trends for the various individual greenhouse gases. The global economic crisis, which had its first impact in Germany at the end of 2008, had a significant effect on emissions. Part of the annual fluctuations in the years 2008-2013 were the result of economic fluctuations in certain sectors.

Releases of carbon dioxide – the great majority of which are caused by stationary and mobile combustion processes – predominate in the overall picture of greenhouse-gas emissions. Due to a disproportionately large decrease in emissions of the other greenhouse gases, the proportion of total greenhouse gases attributable to CO_2 emissions has increased since 1990 (cf. Table 2). All other greenhouse gases together account for only slightly more than one-tenth of greenhouse-gas emissions. Germany's range of greenhouse-gas emissions is typical for a highly industrialised country.

2.2 Description and interpretation of emission trends, by greenhouse gases



* Carbon dioxide emissions apart from LULUCF

Figure 15: Relative development of greenhouse gases in comparison to their levels in 1990

Figure 15 shows the relative development of emissions of the various greenhouse gases since 1990. In the discussion, it must be remembered that the development of each of these greenhouse gases as shown here is largely dominated by specific developments in a single category.

2.2.1 *Carbon dioxide (CO_2)*

The reduction in CO_2 emissions is closely linked to trends in the energy sector. The sharp emissions reduction in this area seen in the early 1990s was primarily the result of restructuring in the new German Länder, including related conversions to cleaner fuels and decommissioning of obsolete facilities. The changes in the fuel mix have continued, to a somewhat lesser degree, through the current report year.

Use of gases, primarily natural gas, as substitutes for solid and liquid fuels is also reflected in emissions trends for stationary combustion systems. While CO_2 emissions from liquid fuels decreased by about 20 %, with respect to their levels in 1990, and emissions from solid fuels decreased by nearly 60 percent, emissions from gaseous fuels increased by over 40 percent.

When these emissions trends are viewed at the level of individual categories, a highly consistent picture emerges. In comparison to 1990 levels, emissions in all categories of energy-related emissions decreased by a total of nearly 200 million t CO_2.

The situation is somewhat different in the transport sector, which is dominated by road transports: CO_2 emissions in this area increased slightly through 1999, and then decreased slightly as a result of reductions in consumption, shifting of refueling to other countries[21], substitution of diesel fuel for gasoline[22] and use of admixtures with biodiesel. In about 2007, the trend began stagnating, in part as a result of ongoing increases in average engine power. In 2013, that stagnation ended as a result of further increases in transport densities and mileages and as a result of decreased use of biofuels (+ 4.5 million t with respect to 2012). The transport sector's CO_2 emissions, at about 158 million t, are thus only slightly below their outset level in 1990 (162 million t).

Trends, taking account of changes with respect to the previous year of the period covered by the report

CO_2 emissions increased, with respect to the previous year, as a result of weather-related higher heating requirements.

2.2.2 Nitrous oxide N_2O

Since 1990, N_2O emissions have decreased by about 42 %. The main emissions areas/sources include agriculture – use of nitrogen-containing fertilisers, and animal husbandry; the chemical industry; and use of fossil fuels. Smaller amounts of emissions are caused by wastewater treatment and product use of N_2O (for example, as an anaesthetic). Industry has had the greatest influence on emissions reductions, especially in the area of adipic acid production – via installation of waste-gas-treatment systems in 1997 and 2009. Via technological reduction measures, the chemical industry's emissions have been reduced by over 96%, with respect to 1990. Since 1999, emissions trends have been strongly influenced by economic trends in the chemical industry sector.

Trends, taking account of changes with respect to the previous year of the reporting period

With regard to the previous year, total emissions increased slightly. Emissions trends within the various sectors varied, however, depending on the fuels involved.

2.2.3 Methane (CH_4)

Methane emissions are caused mainly by animal husbandry in agriculture, waste landfilling and distribution of liquid and gaseous fuels; energy-related and process-related emissions, and emissions from wastewater treatment, play an almost negligible role. Methane emissions have been reduced by 50.3 % since 1990. This trend has been primarily the result of environmental-policy measures (waste separation, with intensified recycling and increasing energy recovery from waste) that has decreased landfilling of organic waste. A second important factor is that use of pit gas from coal mining, for energy recovery, has increased, while overall production of such gas has decreased (via closure of hard-coal mines). Emissions in this area have decreased by nearly 80 % since 1990. Yet another reason for the emissions reductions is that livestock populations in the new Federal Länder have been reduced, with reductions occurring especially in the first half of the 1990s. Repairs and modernisations of

[21] The emissions are calculated on the basis of domestic fuel sales. Fuel quantities not purchased in Germany thus do not enter into the German emissions inventory.

[22] Diesel fuel's share of total fuel consumption in road transports has increased sharply throughout the entire time period. In 1990, nearly two-thirds of road transport emissions were the result of gasoline consumption. Now, this ratio has nearly reversed itself.

outdated gas-distribution networks in that part of Germany, along with improvements in fuel distribution, have brought about further reductions of total emissions.

Trends, taking account of changes with respect to the previous year of the reporting period

With regard to the previous year, emissions decreased slightly. Decreases in landfill emissions, and reductions of energy-related emissions, have been partly offset by increases in agricultural emissions.

2.2.4 F gases

Figure 16 shows emissions trends for so-called "F" gases for the period 1995 through 2012. HFC emissions increased primarily as a result of intensified use of HFCs as refrigerants in refrigeration systems and of increasing disposal of pertinent systems. This more than offset emissions reductions resulting from their reduced use in PUR installation foams. The emissions reductions for PFCs were achieved primarily through efforts of primary aluminium producers and semiconductor manufacturers. The SF_6 emissions reduction until 2003 is due primarily to decreasing use of the gas in automobile tyres since the mid-1990s. In this area, efforts to increase environmental awareness have been successful, resulting in emissions reductions of over 100 t and greenhouse-gas reductions of 2.5 million t of CO_2 equivalents. Similar success has been achieved with soundproof windows, for which production use of SF_6 has been reduced to nearly zero since 1995. And a large share of current and future SF_6 emissions (will) result from open disposal of old windows. Emissions from electricity-transmission facilities have also decreased considerably. Important remaining emissions sources include welding, production of solar cells and production of optical glass fibre.

In Germany, NF_3 is used only in semiconductor and photovoltaics production. In 2013, NF_3 emissions accounted for 0.0018 % of total GHG emissions. In the base year, they accounted for 0.0004% of those emissions. Because those emissions are of such minor importance with regard to total GHG emissions, we have not carried out a separate trend analysis for them.

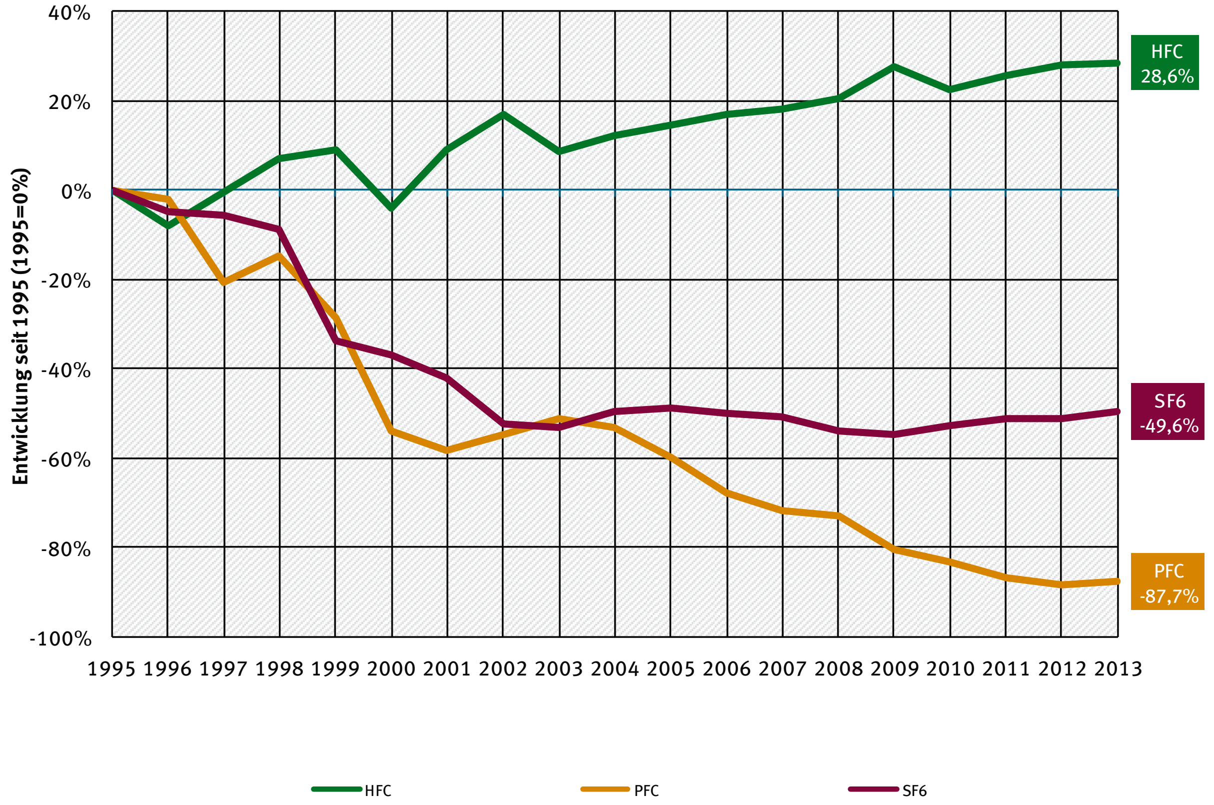


Figure 16: Relative development of F gases in comparison to relevant 1995 levels [Development since 1990 (1990 = 0%)]

2.3 Description and interpretation of emission trends, by greenhouse gases

Energy

In the category of energy-sector emissions, which have been decreasing, combustion-related emissions are governed primarily by CO_2 emissions from stationary and mobile combustion systems (cf. also the results of the key-category analysis). On the other hand, emissions of other greenhouse gases are negligible in this sector. The situation is different solely for emissions that are not combustion-related (category 1.B.). In this area, CO_2 emissions are very low, while emissions trends are clearly shaped by CH_4 emissions caused by distribution of liquid and gaseous fuels. On the whole, energy-related emissions of all greenhouse gases have decreased by 19.9 % since 1990. The transport-related emissions included in greenhouse-gas emissions have decreased by slightly more than 3.2 % during the same period, meaning they have decreased somewhat less than emissions from stationary combustion systems have. For combustion-related emissions, this has been achieved through fuel changeovers and higher energy and technical efficiencies, as well as through increasing use of zero-emissions energy sources. For distribution emissions, it has resulted from increased use of pit gas, modernisation of gas-distribution networks and introduction of vapour-recovery systems in fuel distribution.

Table 438 in the Annex shows the relevant emissions changes, in comparison to the previous year in each case, for the period since 1990. For CO_2 from the energy sector, for example, it is clear that largely temperature-related fluctuations over time – especially variations in winter temperatures – influence heating patterns. Such fluctuations thus affect energy consumption for space heating, thereby having a major impact on annual trends in energy-related emissions.

Industrial processes (including product use)

In the area of emissions from industrial processes, carbon dioxide and nitrous oxide are the predominant greenhouse gases. Relatively noticeable changes in emissions of F gases, on the other hand, have no major impacts on overall trends, because such emissions account for only a small share of total emissions.

Emissions from industrial processes are closely tied to production levels. CO_2 emissions trends, in particular, reflect economic trends in the mineral, chemical and metal-producing industries.

The trend for N_2O emissions has been decoupled from production ever since adipic acid producers' emissions-reducing measures began taking effect. In 1997 and 2010 in particular, those measures yielded considerable reductions in N_2O emissions. Overall since 1990, N_2O emissions have decreased to about one-twentieth of their outset level.

Since 1990, N_2O emissions from solvent use have decreased by about 50 %.

Since 1990, emissions from the totality of all industrial processes and product use, expressed in GHG equivalents, have been reduced by 36.3 %. In comparison to the previous year, a slight decrease of 1.1 % has occurred, thanks to emissions reductions in nearly all industrial sectors.

Agriculture

The decrease in agricultural emissions since 1990, amounting to over 17.5 %, is due primarily to reductions in livestock populations, although it is also due to reductions in emissions from agricultural soils and from fertiliser use.

Land use, land-use changes and forestry

The reduction in greenhouse-gas removals via land-use changes and forestry is due primarily to a change of the sink function in the category "Forest Land remaining Forest Land". In the period 2002 through 2008, the decrease in forests' sink function was due to increasing harvesting of wood, for a range of different types of uses. In 2008, the sink function began increasing again, although it did not reach the level seen in the period 1990 through 2001. This was also due to wood use.

Waste and wastewater

The most significant emissions reduction, at 68.1 %, occurred in the area of waste emissions. In that area, intensified recycling of recyclable materials ("yellow sack" for recyclable materials, Ordinance on Packaging, etc.), and the ban, in effect since June 2005, on landfilling of biodegradable waste, have reduced annual quantities of landfilled waste. All in all, these factors have reduced landfill emissions by 70.6 %. Emissions from wastewater treatment, which also belong to this category, are produced in considerably lower quantities than landfill emissions are. Nonetheless, they also decreased sharply.

The relevant detailed data are presented in Table 439 in Annex Chapter 22.3.

Table 13: Changes in greenhouse-gas emissions in Germany, by categories, since 1990 / since the relevant previous year

Emissions change with respect to 1990; change in %	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013
1. Energy	0.0%	-11.4%	-15.8%	-19.5%	-20.7%	-26.3%	-22.5%	-24.5%	-23.8%	-21.6%
2. Industrial processes	0.0%	-2.7%	-23.1%	-25.1%	-27.1%	-34.8%	-37.7%	-37.1%	-38.0%	-38.7%
3. Agriculture	0.0%	-13.1%	-13.8%	-19.1%	-18.1%	-19.0%	-20.1%	-18.0%	-18.6%	-17.5%
4. Land use, land-use changes & forestry	0.0%	-2.0%	-3.7%	-7.7%	-6.0%	-5.3%	-4.7%	-4.1%	-3.4%	-2.6%
5. Waste	0.0%	0.1%	-25.3%	-44.8%	-55.8%	-59.1%	-62.1%	-64.1%	-66.1%	-68.1%

Emissions change, in each case with respect to the previous year; change in %	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013
1. Energy	0.0%	-0.2%	-0.2%	-2.3%	0.7%	-7.0%	5.2%	-2.7%	0.9%	2.9%
2. Industrial processes	0.0%	-1.8%	4.0%	-4.1%	-4.9%	-10.6%	-4.3%	0.9%	-1.4%	-1.1%
3. Agriculture	0.0%	2.1%	-0.5%	-0.9%	3.7%	-1.1%	-1.3%	2.5%	-0.7%	1.3%
4. Land use, land-use changes & forestry	0.0%	-0.5%	-0.3%	-0.9%	0.7%	0.8%	0.6%	0.6%	0.7%	0.9%
5. Waste	0.0%	-2.5%	-5.1%	-6.5%	-6.9%	-7.3%	-7.3%	-5.4%	-5.5%	-5.9%

Figures do not include CO_2 from LULUCF

2.4 Description and interpretation of trends in emissions of indirect greenhouse gases and of SO_2

The relative development of emissions of indirect greenhouse gases and SO_2 are graphically depicted, in each case as time series since 1990, in Figure 17 and in Table 12. Over this period, considerable reductions of emissions of these pollutants have been achieved. For example, emissions of SO_2 decreased by over 92 %, those of CO decreased by 75.4 %, those of NMVOC decreased by 66.5% and those of NO_X decreased by about 56 %.

The vast majority of emissions of sulphur dioxide, nitrogen oxide and carbon monoxide are caused by stationary and mobile combustion processes. In the category of NMVOC emissions, however, solvent use is the most important emissions factor.

A range of different factors are responsible for this trend. These factors, which differ in the significance and extent of their relevance, include:

- As a result of Germany's reunification in 1990, emissions from the territory of the former GDR in particular made the starting level relatively high.
- In the years that followed, obsolete industrial facilities in the eastern part of Germany were decommissioned. They were replaced, in the great majority of cases, with state-of-the-art new facilities. Non-decommissioned old installations were extensively retrofitted with emissions-reduction and efficiency-enhancing equipment.
- In addition, fuel mixes were changed – in eastern Germany in particular, local-lignite fractions were reduced in favour of energy carriers such as natural gas and petroleum, which produce fewer emissions.
- In the transport sector, newer vehicles equipped with pollutant-reducing technology were introduced.
- In the years since 1990, the immission-protection provisions of the former Federal Republic of Germany have become legally binding for eastern Germany. Following the expiration of provisional rulings, applicable laws have been repeatedly adapted in keeping with technological progress.
- Established legal regulations and market-economic incentives have led to thriftier use of energy and raw materials.

- International legislation, particularly from the European Community, has had an emissions-reducing effect (e.g. the NEC Directive).
- Increasing use of zero-emissions energy sources (electricity/heat from solar and wind systems, and from geothermal systems) has also had an impact on emissions of indirect greenhouse gases, especially in recent years.

Descriptions of the emission calculations for these pollutants, along with additional, detailed parameters influencing the emissions trends for the various individual air pollutants involved, are provided by the Web site of the Federal Environment Agency[23].

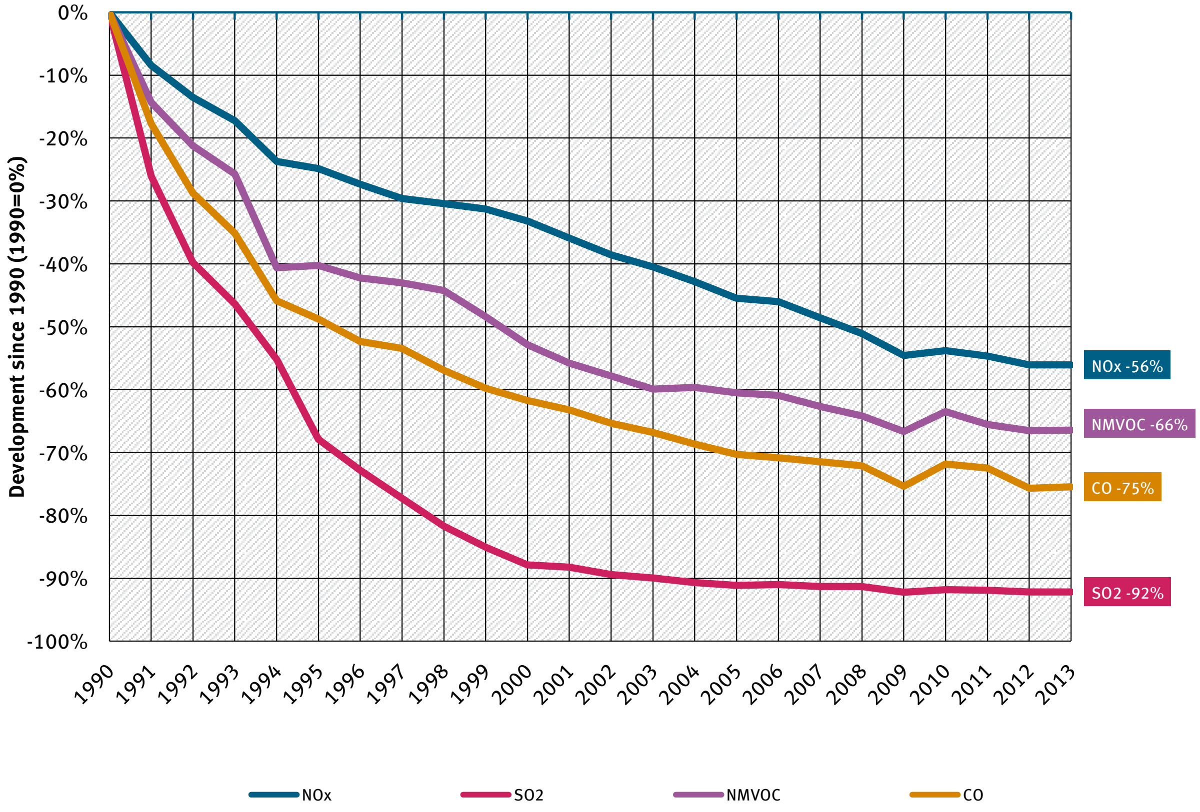


Figure 17: Emissions trends for indirect greenhouse gases and SO_2 [Development since 1990 (1990 = 0%)]

2.5 Description and interpretation of emissions trends with regard to the KP-LULUCF inventory, for aggregated emissions and by activity and greenhouse gas

Germany reports under KP-LULUCF Article 3 (3). In the second commitment period, Germany has to credit forest management activities pursuant to Article 3 (4) of the Kyoto Protocol. The following activities have been selected and reported as voluntary activities under Article 3.4 of the Kyoto Protocol:

1. Cropland management (CM)
2. Grazing land management (GM).

It reports emissions of the greenhouse gases carbon dioxide, methane and nitrous oxide.

[23] http://www.umweltbundesamt.de/emissionen/index.htm and directly in the Informative Inventory Report (IIR): http://iir-de.wikidot.com/

Under Article 3.3, it is reporting removals of -3,297.51 Gg CO_2 equivalent for the year 2013. The removals consist of -6,061.46 Gg CO_2 equivalent of removals via afforestation and reforestation and 2,763.95 Gg CO_2 equivalent of emissions from deforestation. In the category deforestation, it is reporting CO_2 emissions of 2,688.35 Gg CO_2, CH_4 emissions of 23.60 Gg CO_2 equivalent and N_2O emissions of 51.99 Gg CO_2 equivalent.

Under Article 3.4, it is reporting removals of 17,537.84 Gg CO_2 equivalent in the year 2013.

Table 14: Emissions in 2013 for the KP-LULUCF activities afforestation and deforestation, pursuant to Article 3.3, and for forest management, cropland management and grazing land management pursuant to Article 3.4.

Category	Emissions, 2013 [Gg CO_2 equivalent]
KP 3.3 Afforestation/Reforestation	-6,061.46
KP 3.3 Deforestation	2,763.95
KP 3.4 Forest Management	-51,554.69
KP 3.4 Cropland Management	15,695.11
KP 3.4 Grazing Land Management	23,763.27

3 ENERGY (CRF SECTOR 1)

3.1 Overview (CRF Sector 1)

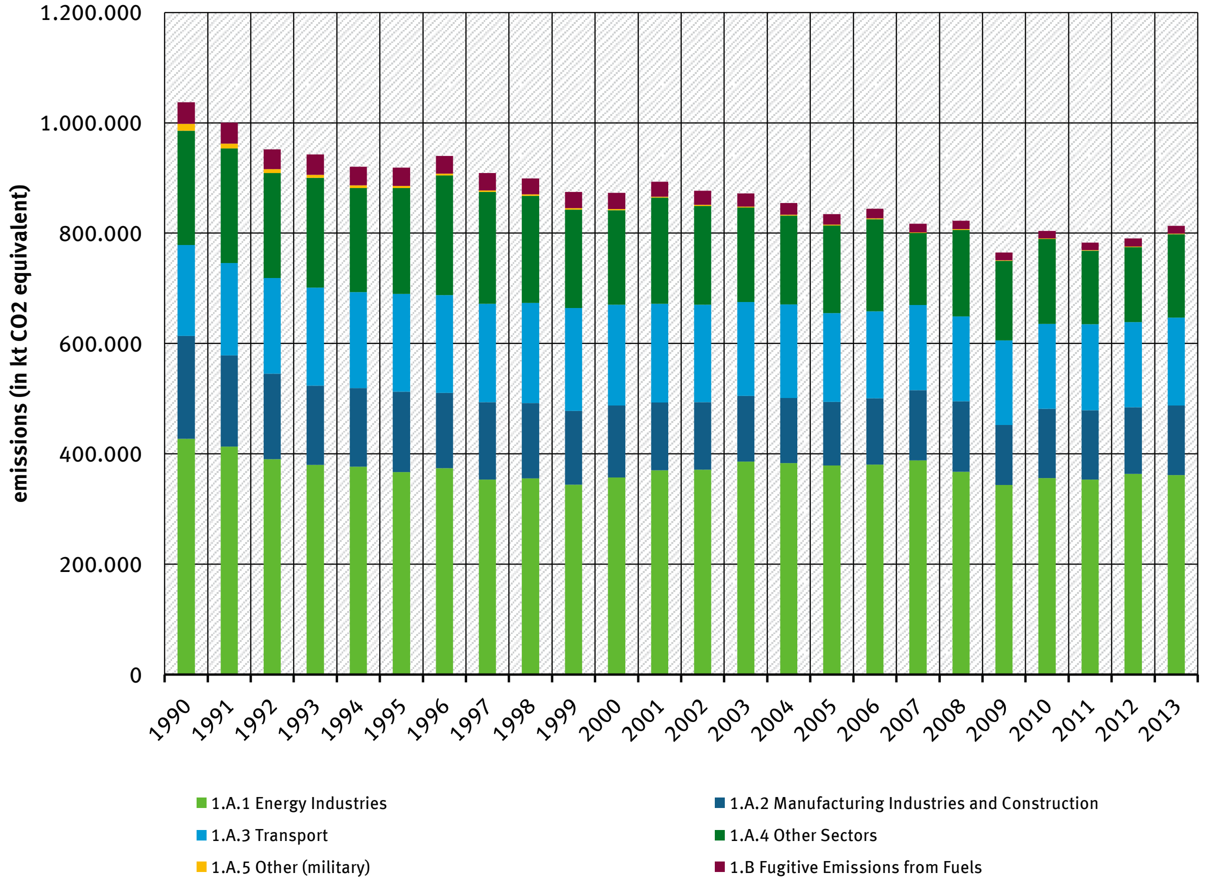


Figure 18: Overview of greenhouse-gas emissions in CRF Sector 1[24,]

For determination of activity data from combustion, different models are used for mobile and stationary sources. The model used for stationary sources is the "Balance of Emissions Sources" ("Bilanz der Emissionsursachen" – BEU), while the model used for mobile sources is the "Transport Emission Estimation Model" (TREMOD). In both models, combustion-related activities are determined and then recorded in the "Central System of Emissions" (CSE) emissions database.

Within the CSE, relevant emissions are then calculated by multiplying these combustion-related activities by the pertinent emission factors (cf. Chapter 18.7). In the process, complete oxidation of the carbon contained in the fuels is assumed.

3.2 Combustion of fuels (1.A)

The activity data for stationary combustion are calculated in the "Balance of Emissions Sources" (BEU) model. The database for this model, which was developed by the Federal Environment Agency, consists of the Energy Balance of the Federal Republic of Germany. The Energy Balance is described in detail in Chapters 18.1 through 18.4.

[24] CO_2 emissions from, and removals in, soils are reported under land-use changes and forestry.

With the help of additional statistics, and of various assumptions, these data are then further disaggregated and supplemented for the relevant energy-transformation and final-consumption sectors. Relevant criteria for this work include permits under immissions-control laws, technologies and differentiation between certain fuels. The model consists of two parts: a sub-model for the old German Länder, covering the years 1987-1994, and a sub-model for all of Germany, covering the years as of 1995. The model for all of Germany has been revised and, in the reports of two research projects (FKZ 203 41 142: ÖKOINSTITUT, 2005 and 204 41 132: ÖKOINSTITUT / DIW, 2007), comprehensively documented. Since 2009, relevant calculations have been carried out with the help of a database-supported system of the BEU that is based on MESAP software and that was developed in the framework of the research projects FKZ 204 42 203/03 and FKZ 360 16 010 (GICON, 2008), via an approach similar to that used for the sub-model for Germany. Data for the new German Länder, for the period 1990-1994, have already been entered into the CSE. The manner in which those data were obtained is described in detail in Chapter 19.1.1.

The following Energy Balance lines are used for determination of emissions-relevant fuel inputs from stationary sources:

A: Transformation inputs (Energy Balance lines 9 through 19)

3. **Public thermal power stations** (line 11) are plants whose operators are sited within the public utlity sector. This category also includes industrial plants which operate their power stations together with electricity utility companies, as joint-venture power stations. The fuel input for electricity generation is reported here. This line of the Energy Balance also includes the fuel input in public thermal power stations attributable to electricity production.
4. **Industrial thermal power stations** (line 12) comprise the following operator groups:
   - Power stations in the hard-coal-mining sector,
   - Power stations in the lignite-mining sector,
   - Power stations in the petroleum-processing sector (refinery power stations),
   - Power stations that generate single-phase power for Deutsche Bahn AG (German Railways) (until 1999, the relevant input amounts for Deutsche Bahn power stations were reported under 1A2f (EB line 12); as of 2000, they have been reported together with public power stations under 1A1a (EB line 11)),
   - Industrial power stations (quarrying, other mining, manufacturing industry).
5. **Hydroelectric, wind-power, photovoltaic systems and other similar systems** (line 14) comprises all systems/plants that generate electricity from biogas, landfill gas, sewage-treatment gas or solid or liquid biomass and feed the electricity into the public grid. In addition, this section of the Energy Balance also reports on fuel inputs in mini-CHP systems fired with natural gas or light heating oil. Since no cut-off limit applies for such systems, this category includes very small systems in the residential and commercial/institutional sectors.
6. **Thermal (CHP) power stations** (line 15): only the fuel input which can be allocated to district heat generation is given. Adding lines 11 and 15 together produces the total fuel input in public thermal power stations. The district heat generated is fed into the public heating grid. These stations also supply industrial customers with process heat.
7. **District heating stations** (line 16): here, the fuel input for the public district heat supply, from heating stations, is given. The facilities are often used to cover peak loads in district heating networks in which the basic load is met by thermal power stations.

B: Energy consumption in the transformation sector (Energy Balance lines 33 through 39)

8. Lines 33 to 39 and the total line 40 (**Energy consumption in the transformation sector**) include the fuel input for heat generation which is needed to operate the transformation stations. No distinction is made here with regard to the type of heat generation involved. This means that fuel inputs for heat generation in combined heating and power stations, steam and hot water boilers and process firing installations are combined. There is an inconsistency in the Energy Balance with respect to summing-up for lignite pits and briquette plants. Since 1980, this own consumption has been listed together with production-related transformation inputs of briquette plants, in line 10. As a result, the emissions-causing inputs within own consumption can no longer be read out of the Energy Balance; they must be calculated from the transformation input. The fuel inputs used to generate heat in combined heat and power generation stations, together with fuel inputs used for electricity generation by the power stations of hard coal pits, lignite pits and refinery power stations, combine to form the total fuel input in such plants. Deduction, from the total listed in line 40, of fuel inputs for heat generation in power stations leaves the quantity of fuel used in process firing installations, steam and hot water boilers.

C: Final energy consumption (Energy Balance lines 46 through 67)

9. **Final energy consumption by industry** (line 60 of the Energy Balance) refers to the fuel used for heat generation which is required for both production purposes and space heating. Here as well, no distinction is made with regard to the type of heat generation involved. Hence, a part of the final energy consumption in these categories, together with industrial power stations' fuel input for generating electricity, constitutes the total fuel input in such facilities.
10. The data on **Final energy consumption in the residential sector** (line 66 of the Energy Balance) comprise fuel inputs for heat generation and include the application areas of heating, water heating and cooking.
11. The data on **final energy consumption in the commercial/institutional sector and by other consumers** (line 67 of the Energy Balance) comprise fuel inputs used for hot water production, space heating and process-heat generation in this sector/area.

The Energy Balance data scheme is no longer able to accommodate all of the diverse requirements of national and international energy and emissions reporting. For example, the Energy Balance combines fuel inputs

- in facilities with different requirements under immission protection legislation (e.g. large furnaces, medium-sized furnaces, small furnaces, waste incineration plants);
- in plants that operate according to different technical principles (e.g. steam turbine power stations, gas turbine power stations, combustion-engine stations);
- that exhibit regional peculiarities (e.g. different individual mining regions have different qualities of crude lignite);
- with different source-category allocations in national and international emissions reporting;
- that are listed in different Energy Balance lines, in keeping with their intended purpose (for electricity or heat generation), but are used in a single facility group (e.g. steam turbine power stations).

These characteristics have impacts on emissions behaviour. In order to make allowance for the various differing requirements that thus arise, the Energy Balance data in the model *Balance of Emission Causes* (BEU) are disaggregated, using additional statistics as well as the Federal Environment Agency's own calculations. The following Figure 19 provides an overview of the relevant structure:

Balance of emission causes (BEU)

The categories include:

- Public thermal power stations,
- Hard coal mining,
- Lignite mining,
- Deutsche Bahn AG (until 1999),
- Production of refined petroleum products,
- District heating stations,
- Other energy transformation
- Quarrying of non-metallic minerals, other mining and manufacturing industry (further sub-classification of process combustion),

(The residential, commercial/institutional and other consumers sectors are listed and analysed directly within the CSE, outside of the BEU model.)

The types of facilities involved include:

- Steam turbine power stations,
- Gas turbine power stations,
- Gas and steam turbine power stations,
- Motor power stations,
- Boiler furnaces (excluding power station boilers),
- Process furnaces (sub-classified into 12 processes).

By fuels/energy sources:

- About 40 different fuels

On the basis of immission protection legislation provisions, the following are differentiated:

- Facilities under the 13th BImSchV,
- Facilities under the 17th BImSchV,
- Facilities under the 1st BImSchV,
- Installations under the Technical Instructions on Air Quality Control (TA Luft)
- Installations not subject to licensing

Abbreviations:

BImSchV Ordinance on the Execution of the Federal Immission Control Act,

TA-Luft First General Administrative Provision on the Federal Immission Control Act (Clean Air Directive)

Figure 19: Characteristics of the Federal Environment Agency's structure of the Balance of Emission Causes, for disaggregation of the Energy Balance

The BEU model is designed to provide a data structure that can be used in meeting a range of different reporting obligations. In particular, finer disaggregation has been needed for determination of emissions of "classical" air pollutants, including calculation of nitrous oxide and methane emissions.

Despite the conversion of the Energy Balance to the classification of industrial sectors (WZ 93) and altered grouping of energy resources from the year 1995 onwards, it has been possible to fit the data within the outlined basic structure; this has facilitated preparation of consistent time series. As of 2008, classification of economic sectors (Wirtschaftszweige = WZ), in energy statistics, was again changed – from the "WZ 2003" standard to the "WZ 2008" standard. As a result, activity data relative to process combustion are now being taken from individual statistics, and documented, in keeping with the relevant key for the change (STATISTISCHES BUNDESAMT (FEDERAL STATISTICAL OFFICE) 2008: "Umsteigeschlüssel WZ 2003 auf WZ 2008" (key for the change from WZ 2003 to WZ 2008))

The structure and the characteristics of the Balance of Emissions Sources (BEU) were presented and described in the 2011 National Inventory Report – in Figure 20 and in Tables 16 through 22 (in tabular form). Since there have been no structural changes in the BEU since then, here we simply refer to that source, which assigns the structural elements of the BEU to the database of the Central System of Emissions (CSE), via unique names.

In addition to being classified in the aforementioned structure, the various fuels and energy sources are listed individually in the database. In the main, the various fuel categories are oriented to the Energy Balance. In some cases, there is a need to subdivide the individual fuel categories. This is done with the help of energy statistics, coal-industry statistics and a smaller number of sets of association statistics. The various fuel-quality levels, with their various carbon-content levels, are combined, in keeping with reporting provisions, in the following five categories: gases, liquid fuels, solid fuels, biomass and other fuels. Because of the many different fuels involved, and because the fuels' shares of the various categories vary, the implied emission factors listed in the CRF tables often change.

To determine activity data for waste in waste incineration plants and for co-combustion in combustion systems in the sectors Public electricity and heat generation (1.A.1) and Manufacturing (1.A.2), the Federal Environment Agency, working in the framework of a research project of its own, has carried out a thorough evaluation of fuel inputs in energy statistics (Energiestatistik) 060 and 066 (*STATISTISCHES BUNDESAMT*, 2013) and waste statistics (*STATISTISCHES BUNDESAMT, FS 19 Reihe 1*) of the Federal Statistical Office. To ensure that all fuel quantities were taken into account, as completely as possible, the relevant waste quantities, broken down by sectors and individual industrial sectors, were carefully compared. To enable comparison of the two sets of statistics, waste quantities from waste statistics were allocated to the same fuel groups used in energy statistics: solid biomass, other petroleum products, sewage sludge, household and settlement waste and industrial waste. Industrial waste and household waste were classified in keeping with the Ordinance on the European Waste Catalogue (AVV), with industrial waste including all waste with waste-classification numbers beginning with the numbers 01 through 19.

The result shows that in recent years the fuel quantities recorded in energy statistics have continually increased. The reasons for this include the fact that in recent years more and more solid biomass (primarily waste and scrap wood) and processed settlement waste have been used for energy generation. Overall, the waste quantities in energy statistics – after deduction of solid biomass – are still smaller, however, than those in waste statistics. For that reason, the activity data for household/municipal and industrial waste are taken from the Energy Balance and then supplemented with the difference relative to waste statistics. In the Energy Balance, waste wood is listed as solid biomass, and not as waste. Consequently, to prevent double counting, in waste statistics it has to be deducted from the listed inputs for waste-incineration and combustion systems.

With regard to waste composition, as of the NIR 2006 the fossil and biogenic fractions of household / municipal waste are listed separately, in a ratio of 1:1. That split factor has been confirmed via a published research project, "Use of biogenic waste fractions for energy generation" ("Nutzung der Potenziale des biogenen Anteils im Abfall zur Energieerzeugung") (UBA, 2011; Förderkennzeichen (funding reference number) 3707 33 303). The biogenic fractions of industrial waste vary widely by industrial sector and installation type. Accordingly, for the sector Manufacturing (1.A.2), and for the sectoral classifications iron and steel, paper, cement and lime, detailed substitute-fuel data continue to be used that are provided by the associations German Iron and Steel Institute (VDEh), German Pulp and Paper Association (VDP), the German Lime Association (BV Kalk) and the German Cement Works Association (VDZ).

Figure 20 schematically shows all important sources of data on use of waste as fuel inputs for energy generation.

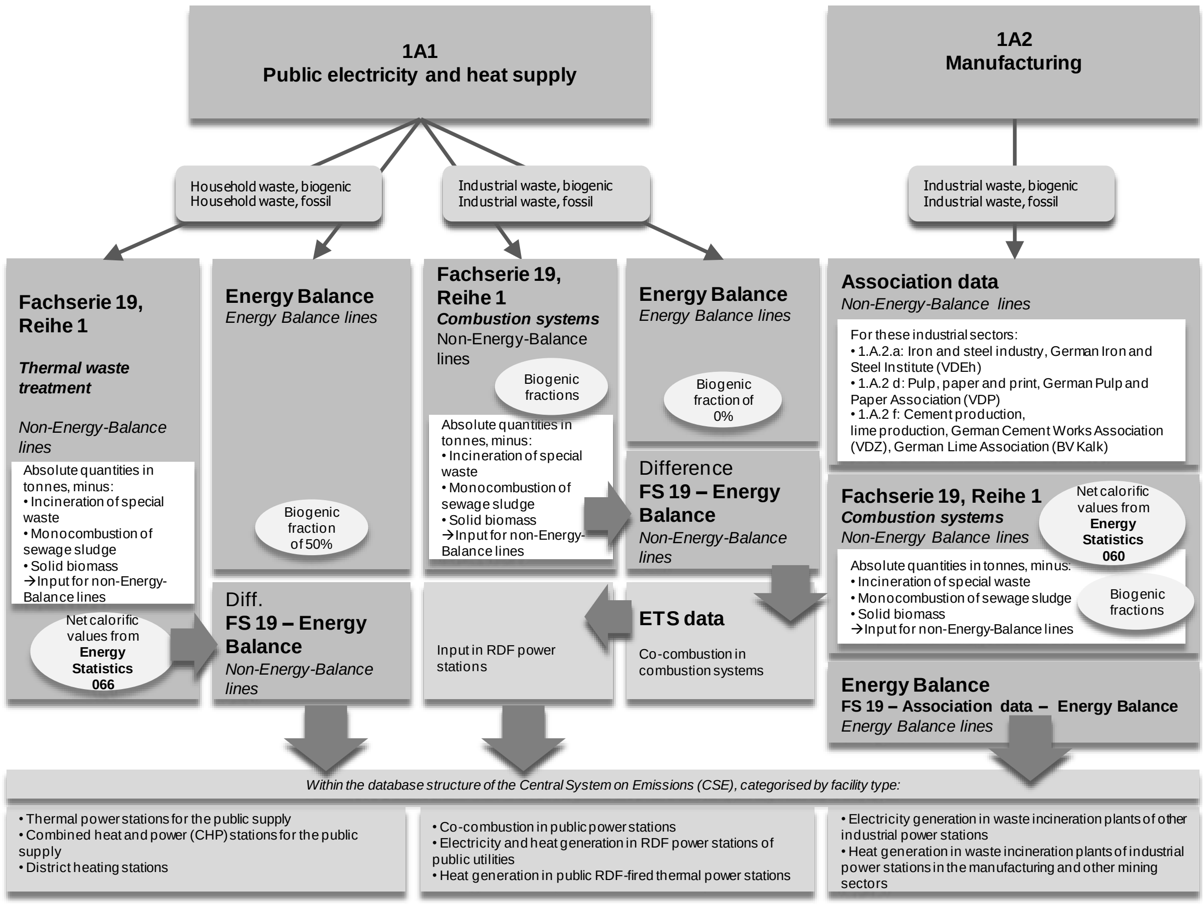


Figure 20: Sources of data, in the context of the inventory of greenhouse-gas emissions, on use of waste as fuel inputs for energy generation

3.2.1 Verification of the sectoral approach for CRF 1.A

3.2.1.1 Comparison with the CO_2 Reference Approach

Reporting on combustion-related CO_2 emissions is centrally important within the context of international climate protection, because such emissions account for a predominant share of total emissions. To this end, industrialised countries routinely adopt the category-specific approach, which addresses the level of individual energy consumption sectors and therefore permits greater differentiation in analysis of emissions structures. To provide a simplified and comparative approach, the IPCC has developed the *Reference Approach*. The CO_2 emissions calculated via that approach, on the basis of primary energy consumption (domestic fuel inputs), have to be compared with the emission results obtained via the *Sectoral Approach*.

The Reference Approach was carried out for all years as of 1990. In each case, the basis for relevant calculations has consisted of the National Energy Balances on primary energy consumption, which have been published for years through 2013. At the time the inventory was prepared, only a provisional balance was available for the year 2013. The data in that balance have since been revised, and thus are not included here in their original form.

The results of the Reference Approach are compiled in Table 15. In Figure 21 and Figure 22, they are compared with other available data sets, such as data of the IEA and of individual German Länder. The CO_2 emissions as calculated with the Reference Approach differ by no more than - 2.43 % (2010) and + 1.35 % (1990) from the results obtained with the Sectoral Approach.

Table 15: Comparison of CO_2 emissions from gaseous fossil fuels, as listed in the CRF Reporter for a) the Sectoral Approach and b) the Reference Approach; emissions quantities in [kt]

	1990	1995	2000	2005	2010	2011	2012	2013
1.AB	999,162	865,638	826,012	807,918	762,698	744,818	753,564	783,883
1.AA	985,867	877,696	836,484	808,465	781,686	760,138	766,205	789,610
Difference	**1.35 %**	-1.37 %	-1.25 %	-0.07 %	**-2.43 %**	-2.02 %	-1.65 %	-0.73 %

3.2.1.2 Verification with other data sets available for Germany

Below, for verification purposes, the results of the detailed category-based calculation of energy-related CO_2 emissions for Germany, carried out in accordance with the specifications of the *IPCC Guidelines*, are compared with other available (for Germany) national and international data records on energy-related CO_2 emissions for the years 1990 to 2012. For 2013, these comparative data are not yet available.

In the comparison, the calculation results are compared with data:

- from the IEA (category-specific approach and Reference Approach), and
- from the CO_2 calculations performed at Länder level.

Table 16 and Figure 21 compare the results of the approaches for calculating CO_2 emissions, throughout the different years involved. The key development trends emerge in all calculation approaches, including the Reference Approach, albeit at differing levels. In Figure 22, the relative discrepancies in the data records are depicted in order to illustrate these level differences.

Nevertheless, on the whole, these comparisons clearly confirm the CO_2 emissions figures calculated for Germany. On an average for the years 1990 to 2012, the total national energy-related emissions calculated with the *Sectoral Approach* (cf. UBA (CRF 1.A)) differ as follows from the relevant comparative data sets:

- IEA (detailed Sectoral Approach): IEA (SA)) 1.5 %
- IEA (Reference Approach: IEA (RA)) 0.6 %
- National Reference Approach (UBA (RA)) 0.9 %
- Results of the Länder[25] 0.4%

[25] Difference with respect to UBA (CRF 1.A), incl. CO_2 from international air transports (CRF 1.D.1.a);

Table 16: Comparison of CO_2 inventories with other independent national and international results for CO_2 emissions

Results, difference	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
IEA statistics, SA (sectoral approach)	**949.7**	**924.8**	**886.5**	**879.9**	**868.5**	**867.8**	**896.5**	**865.8**	**858.9**	**826.9**
How IEA (SA) differs from UBA (CRF 1.A)	-3.7	-2.9	-2.2	-1.9	-1.1	-1.1	-0.4	-0.4	-0.5	-1.3
IEA statistics, RA (reference approach)	**970.9**	**939.8**	**900.3**	**886.6**	**875.4**	**875.8**	**901.5**	**876.1**	**870.6**	**835.1**
How IEA RA differs from UBA (CRF 1.A)	-1.5	-1.3	-0.7	-1.2	-0.3	-0.2	0.2	0.8	0.9	-0.3
How IEA RA differs from UBA RA	-2.8	-1.6	-0.6	-1.2	-0.1	1.2	1.3	1.8	2.1	0.7
Results of the Länder (energy)	**981.7**	**963.2**	**917.1**	**912.5**	**890.5**	**893.7**	**914.9**	**890.8**	**888.0**	**862.0**
How the Länder results (energy) differ from UBA	-1.6	0.0	-0.3	0.2	-0.3	0.1	-0.1	0.6	1.0	0.7
Reference Approach UBA (RA)	**999.2**	**954.9**	**905.9**	**897.6**	**876.5**	**865.6**	**890.0**	**860.7**	**852.9**	**829.2**
How UBA RA differs from UBA (CRF 1.A)	1.3	0.3	-0.1	0.1	-0.2	-1.4	-1.1	-1.0	-1.1	-1.0
Sectoral approach UBA (CRF 1.A)	**985.9**	**952.0**	**906.7**	**897.0**	**878.3**	**877.7**	**899.8**	**869.4**	**862.8**	**837.6**
International air transports	*11.9*	*11.7*	*12.9*	*13.8*	*14.5*	*15.0*	*15.7*	*16.2*	*16.8*	*18.1*

Results, difference	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
IEA statistics, SA (sectoral approach)	**825.0**	**843.3**	**830.7**	**831.4**	**815.6**	**799.6**	**811.8**	**779.3**	**786.2**	**730.4**
How IEA (SA) differs from UBA (CRF 1.A)	-1.4	-1.8	-1.6	-1.2	-1.3	-1.1	-0.9	-1.8	-1.6	-1.7
IEA statistics, RA (reference approach)	**841.8**	**870.3**	**844.4**	**839.2**	**836.5**	**811.4**	**819.3**	**800.8**	**801.7**	**742.2**
How IEA RA differs from UBA (CRF 1.A)	0.6	1.3	0.0	-0.2	1.2	0.4	0.0	0.9	0.3	-0.1
How IEA RA differs from UBA RA	1.9	2.6	0.8	-0.6	1.0	0.4	0.1	1.4	1.3	0.8
Results of the Länder (energy)	**863.1**	**887.6**	**864.5**	**860.2**	**848.3**	**836.5**	**842.7**	**819.7**	**825.5**	**772.9**
How the Länder results (energy) differ from UBA	0.9	1.1	0.2	0.0	0.1	0.6	-0.1	0.1	0.1	0.7
Reference Approach UBA (RA)	**826.0**	**847.9**	**837.6**	**844.5**	**828.1**	**807.9**	**818.6**	**789.6**	**791.6**	**736.6**
How UBA RA differs from UBA (CRF 1.A)	-1.3	-1.3	-0.8	0.4	0.2	-0.1	-0.1	-0.5	-1.0	-0.9
Sectoral approach UBA (CRF 1.A)	**836.5**	**858.9**	**844.2**	**841.1**	**826.4**	**808.5**	**819.4**	**793.6**	**799.2**	**743.0**
International air transports	*19.2*	*18.7*	*18.6*	*19.0*	*20.8*	*22.7*	*23.9*	*24.8*	*25.1*	*24.4*

Results, difference	2010	2011	2012	2013
IEA statistics, SA (sectoral approach)	**769.9**	**742.2**	**755.3**	**NA**
How IEA (SA) differs from UBA (CRF 1.A)	-1.5	-2.4	-1.4	NE
IEA statistics, RA (reference approach)	**775.3**	**752.5**	**NA**	**NA**
How IEA RA differs from UBA (CRF 1.A)	-0.8	-1.0	NE	NE
How IEA RA differs from UBA RA	1.6	1.0	NE	NE
Results of the Länder (energy)	**805.6**	**784.1**	**793.3**	**NA**
How the Länder results (energy) differ from UBA	0.0	0.1	0.3	NE
Reference Approach UBA (RA)	**762.7**	**744.8**	**753.6**	**783.9**
How UBA RA differs from UBA (CRF 1.A)	-2.4	-2.0	-1.6	-0.7
Sectoral approach UBA (CRF 1.A)	**781.7**	**760.1**	**766.2**	**789.6**
International air transports	*24.2*	*23.2*	*25.0*	*25.4*

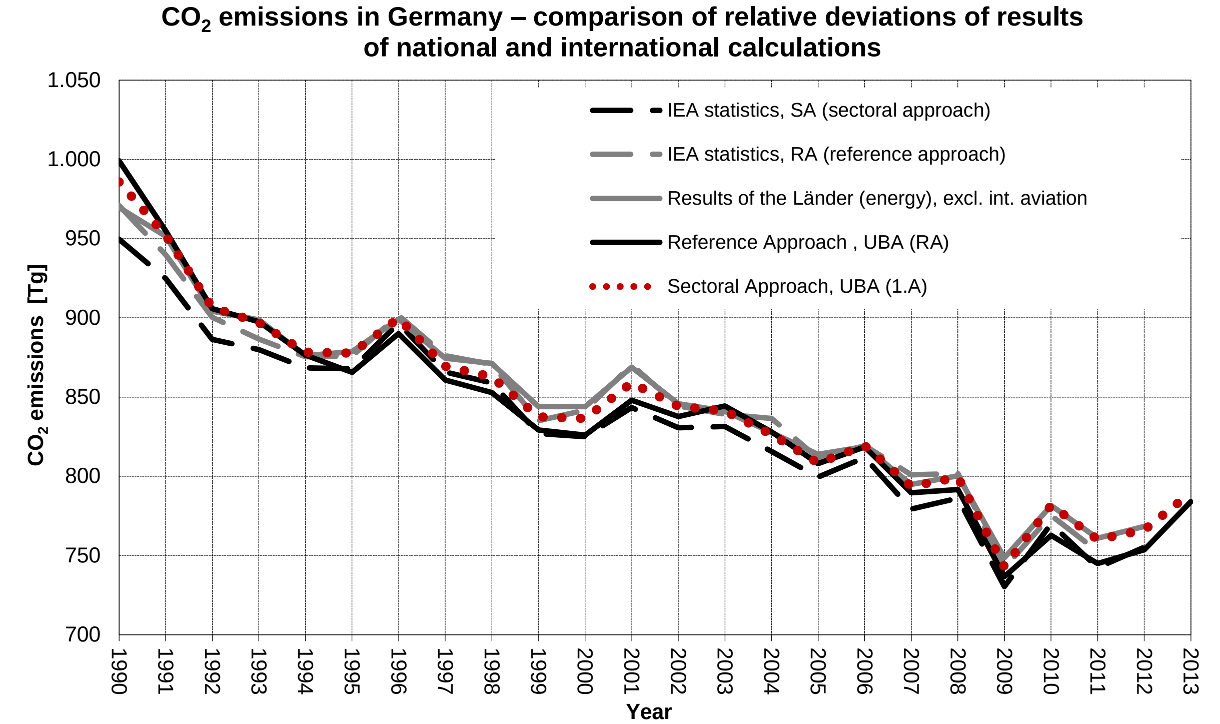


Figure 21: CO_2 emissions in Germany – comparison of results of national and international calculations

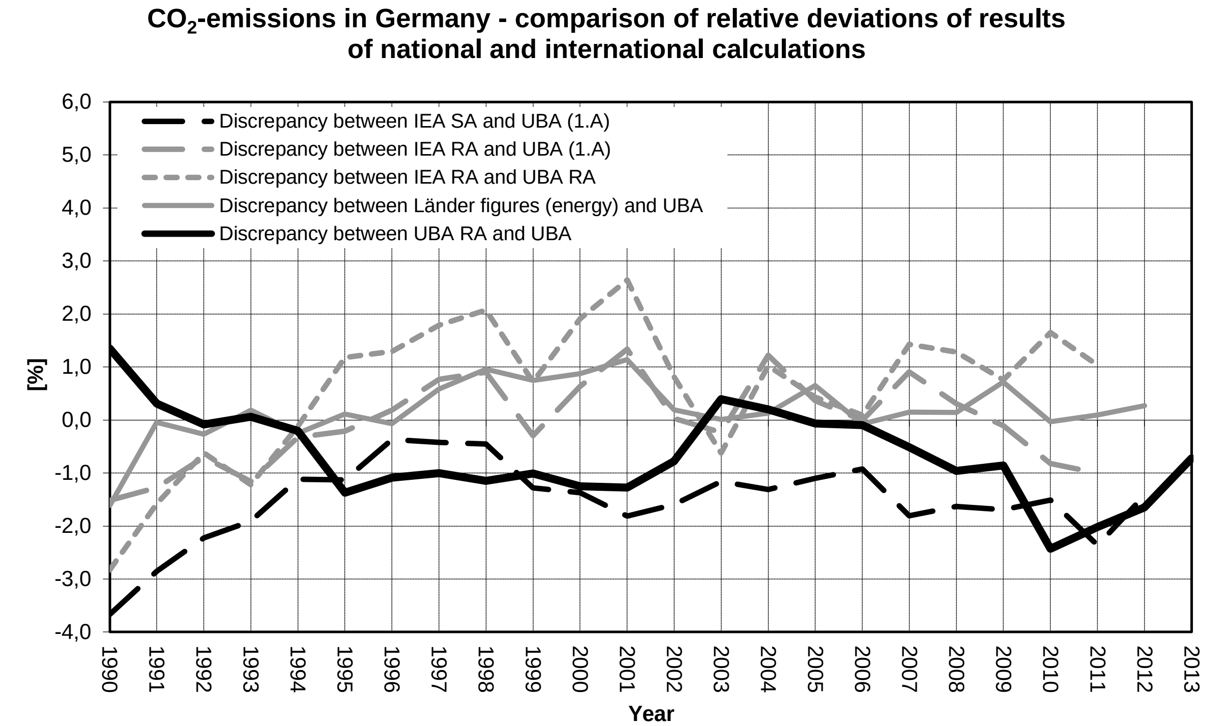


Figure 22: CO_2 emissions in Germany – comparison of relative discrepancies of national and international calculations

3.2.1.2.1 Comparison with the IEA results

The data used are data published annually, in updated form, by the IEA (most recently: OECD/IEA 2014). Since the method for determining, processing and applying the basic data used for this purpose currently is not precisely comparable with the national procedure in

Germany at present, and relevant addition methodological information is lacking – particularly information with regard to the detailed data used – this comparison is provided only for reasons of completeness.

In spite of this restriction, the comparison with the results obtained with IEA's Sectoral Approach confirms the data obtained via the national, detailed method: The average discrepancy over the period to date – 23 years – is 1.5 %. In all of the years concerned, the comparable national emissions are higher than the pertinent results obtained by the IEA. The individual discrepancies vary throughout a range of - 3.7 % (1990) to - 0.4 % (1969).

The results of the Reference Approach used by the IEA differ from those of the Reference Approach carried out in Germany by 1.2 %, over a 21-year average. That information is included here solely for reasons of tradition. It is of limited conclusiveness, since the figures in the IEA's publication of the previous year have been used here. In the aforementioned current edition, the results of the IEA Reference Approach have not been included. As a result of this constraint, no pertinent discussion is provided here.

3.2.1.2.2 Comparison with the data obtained for the individual Länder

The German Länder publish data on their own CO_2 emissions (cf.: http://www.lak-energiebilanzen.de/dseiten/co2BilanzenAktuelleErgebnisse.cfm). Regarding the relevant procedures, responsible and participating institutions, and methodological descriptions, we call the reader's attention to that Web site and to the pertinent more detailed remarks in the NIR 2009.

The following section presents a comparison, for energy-related CO_2 emissions, of a) available Länder results published to date in the Balance of Emissions Sources (BEU) and b) inventories calculated at the national level. One difficulty hampering the comparison is that pertinent information for the individual Länder is not always available in the form of complete time series. Gaps in the time series were closed primarily via interpolation. Since data for 2013 are currently available for only a few German Länder, the comparison is limited to the period 1990 to 2012.

A significant aspect of the comparison is that the methods used in the Energy Balances of the Länder, and for the CO_2-emissions calculations based on those balances, do not correct for the fuel used in international air transports. For this reason, the a) results of the German Länder (states) have to be compared with b) the total energy-related emissions (1.A) in the national inventory, plus the emissions, reported as memo items, for international air transports (1.D.1.a).

Table 17: Comparison of the results of CO_2 calculations of individual Länder with corresponding figures from the federal inventories

State (Land)	1990	1991	1992	1993	1994 [Gg CO_2]	1995	1996	1997	1998	1999
Baden-Württemberg	74,374	78,590	78,036	78,673	74,535	78,074	81,759	78,570	80,080	77,379
Bavaria	84,544	88,972	87,041	90,335	87,871	88,307	92,265	89,837	92,708	90,590
Berlin	26,941	27,957	25,234	26,643	25,531	24,445	24,726	23,560	22,876	23,693
Brandenburg	81,894	66,751	58,894	57,104	54,011	50,791	50,312	50,762	59,255	57,784
Bremen	13,433	13,586	12,903	12,517	13,341	13,239	14,256	14,170	13,857	12,793
Hamburg	12,743	14,226	13,116	13,813	13,361	13,467	14,572	13,940	*13,651*	*13,362*
Hesse	50,338	53,945	53,267	56,060	56,201	56,126	60,233	57,571	57,464	55,017
Mecklenburg – West Pomerania	15,539	10,757	9,360	9,473	9,510	10,233	11,636	10,654	10,413	10,627
Lower Saxony	77,138	82,276	*80,915*	*79,553*	78,192	*78,334*	78,475	*79,440*	80,405	*77,316*
North Rhine – Westphalia	299,028	309,888	306,287	300,041	295,874	303,349	312,345	307,064	304,784	294,014
Rhineland-Palatinate	27,394	29,448	28,914	30,248	30,274	31,490	31,463	31,646	31,167	30,311
Saarland	23,708	25,767	24,398	23,214	24,313	23,133	23,852	21,825	23,795	22,833
Saxony	91,465	77,105	64,059	66,046	62,988	61,349	56,223	51,036	37,167	35,116
Saxony-Anhalt	50,863	38,085	31,892	27,887	26,307	25,200	25,652	25,294	25,261	26,900
Schleswig-Holstein	24,200	23,826	24,082	24,590	24,191	22,940	23,517	22,654	22,426	21,868
Thuringia	28,098	22,071	18,687	16,334	13,992	13,240	13,641	12,806	12,713	12,438
Result for all German Länder	**981,699**	**963,249**	**917,084**	**912,531**	**890,493**	**893,716**	**914,927**	**890,828**	**888,021**	**862,041**
Sectoral approach UBA (CRF 1.A)	985,867	951,954	906,657	896,998	878,289	877,696	899,832	869,447	862,825	837,605
International air transports (CRF 1.D.1.a)	11,870	11,749	12,881	13,831	14,457	14,989	15,724	16,224	16,756	18,054
National result (CRF 1.A + CRF 1.D.1.a)	**997,737**	**963,703**	**919,537**	**910,829**	**892,745**	**892,685**	**915,556**	**885,670**	**879,581**	**855,659**
Difference between the Länder results and the national results (Gg)	**-16,038**	**-454**	**-2,453**	**1,702**	**-2,252**	**1,031**	**-629**	**5,158**	**8,440**	**6,382**
Difference between the Länder results and the national results (%)	**-1.6**	**0.0**	**-0.3**	**0.2**	**-0.3**	**0.1**	**-0.1**	**0.6**	**1.0**	**0.7**

State (Land)	2000	2001	2002	2003	2004 [Gg CO_2]	2005	2006	2007	2008	2009
Baden-Württemberg	74,940	80,108	76,549	75,598	74,768	77,222	78,283	70,952	72,556	66,153
Bavaria	88,705	90,377	84,578	83,783	83,190	80,541	81,879	74,972	80,430	77,930
Berlin	23,661	24,068	21,281	21,249	20,184	19,998	19,915	17,466	18517	17928
Brandenburg	60,564	60,928	61,537	57,910	58,882	59,910	58,273	58,173	56,587	52,968
Bremen	14,079	14,137	14,031	14,667	13,057	12,222	12,704	13,645	13,056	12,603
Hamburg	*13,073*	*12,784*	*12,495*	12,650	12,569	12,299	12,432	11,926	11,855	11,786
Hesse	56,011	57,817	54,897	55,528	54,787	54,441	53,170	50,916	52,159	49,128
Mecklenburg – West Pomerania	10,256	10,718	10,908	10,696	10,906	10,354	11,141	10,053	10,844	9,522
Lower Saxony	74,228	*73,145*	72,061	*71,040*	70,019	*70,158*	70,298	*69,898*	69,402	65,810
North Rhine – Westphalia	293,987	299,969	295,293	295,885	291,555	282,533	287,140	289,557	286,158	260,666
Rhineland-Palatinate	28,853	29,574	27,793	26,787	26,432	26,399	27,110	25,596	27,453	26,181
Saarland	23,459	23,260	22,964	23,278	23,917	24,799	23,577	25,714	22,961	18,511
Saxony	41,552	48,842	49,038	49,625	48,476	47,019	48,295	46,854	46,927	47,980
Saxony-Anhalt	26,301	26,840	27,518	28,171	27,145	27,846	27,821	26,477	26,973	26,772
Schleswig-Holstein	21,378	22,737	21,455	21,401	20,592	19,356	19,339	17,032	18715	18,430
Thuringia	12,059	12,339	12,066	11,924	11,812	11,450	11,283	10,422	10,911	10,526
Result for all German Länder	**863,106**	**887,643**	**864,465**	**860,192**	**848,291**	**836,547**	**842,659**	**819,652**	**825,504**	**772,894**
Sectoral approach UBA (CRF 1.A)	836,484	858,888	844,185	841,143	826,422	808,465	819,393	793,632	799,216	742,989
International air transports (CRF 1.D.1.a)	19,165	18,741	18,626	18,978	20,771	22,687	23,884	24,820	25,121	24,399
National result (CRF 1.A + CRF 1.D.1.a)*	**855,649**	**877,629**	**862,810**	**860,121**	**847,194**	**831,152**	**843,276**	**818,452**	**824,338**	**767,389**
Difference between the Länder results and the national results (Gg)	**7,457**	**10,014**	**1,654**	**71**	**1,097**	**5,395**	**-617**	**1,200**	**1,166**	**5,506**
Difference between the Länder results and the national results (%)	**0.9**	**1.1**	**0.2**	**0.0**	**0.1**	**0.6**	**-0.1**	**0.1**	**0.1**	**0.7**

State (Land)	2010	2011	2012	2013	2014 [Gg CO_2]	2015	2016	2017	2018	2019
Baden-Württemberg	67,565	66,336	65,889							
Bavaria	80022	78505	77968							
Berlin	19772	17680	18833							
Brandenburg	55792	56347	57670							
Bremen	13924	13250	13576							
Hamburg	12114	11584	11408							
Hesse	50,259	47,964	48,822							
Mecklenburg – West Pomerania	10,985	10,364	10,997							
Lower Saxony	67,488	66,623	64,455							
North Rhine – Westphalia	275301	268045	271966							
Rhineland-Palatinate	27336	25537	25451							
Saarland	19116	20678	21567							
Saxony	48737	46833	48900							
Saxony-Anhalt	27375	27173	27771							
Schleswig-Holstein	19043	17069	17662							
Thuringia	10771	10102	10373							
Result for all German Länder	**805,600**	**784,090**	**793,308**							
Sectoral approach UBA (CRF 1.A)	781,686	760,138	766,205							
International air transports (CRF 1.D.1.a)	24,153	23,205	24,973							
National result (CRF 1.A + CRF 1.D.1.a)*	**805,839**	**783,344**	**791,177**							
Difference between the Länder results and the national results (Gg)	**-239**	**746**	**2,131**							
Difference between the Länder results and the national results (%)	**0.0**	**0.1**	**0.3**							

*) A correction is required, since at the Länder level energy consumption is not corrected to taken account of international air transports!

Remark: The italicised figures, in grey table cells, are not part of consistent time series and were generated via gap-closure procedures (see text).

In terms of trend, the comparison found excellent agreement between the combined Länder results and the Federal inventory. On an average for the 23 years in question, the total CO_2 emissions for the Länder differed by 0.4 % from the Federal result. The extremes of the deviations ranged from -1.6 % in 1990 to 1.1 % in 2001.

3.2.1.2.3 Planned improvements

Following the reporting process, the results of the comparison are regularly discussed, and reviewed with regard to potential for improvement, with the representatives of the Länder Working Group on Energy Balances (Länderarbeitskreis Energiebilanzen). At present, no concrete plans for further improvements are in place.

3.2.2 International bunker fuels

3.2.2.1 Emissions from international transports (1.D.1.a/1.D.1.b)

The area of international transports is divided into international civil aviation (1.D.1.a) and international maritime navigation (1.D.1.b).

3.2.2.2 Emissions from international air transports (1.D.1.a)

3.2.2.2.1 Category description (1.D.1.a)

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS (Tier 2)	NS/IS/M	CS / D*
CH_4	CS (Tier 3)	NS/IS/M	CS (M)
N_2O	CS (Tier 3)	NS/IS/M	CS (M)
NO_X, CO, NMVOC, SO_2	CS (Tier 3)	NS/IS/M	CS (M)

* co-combusted lubricants

The emissions from consumption of fuels for international civil aviation are included in the inventory calculations, but they are not reported as part of the national overall inventories, and thus they are not included in key-category analysis.

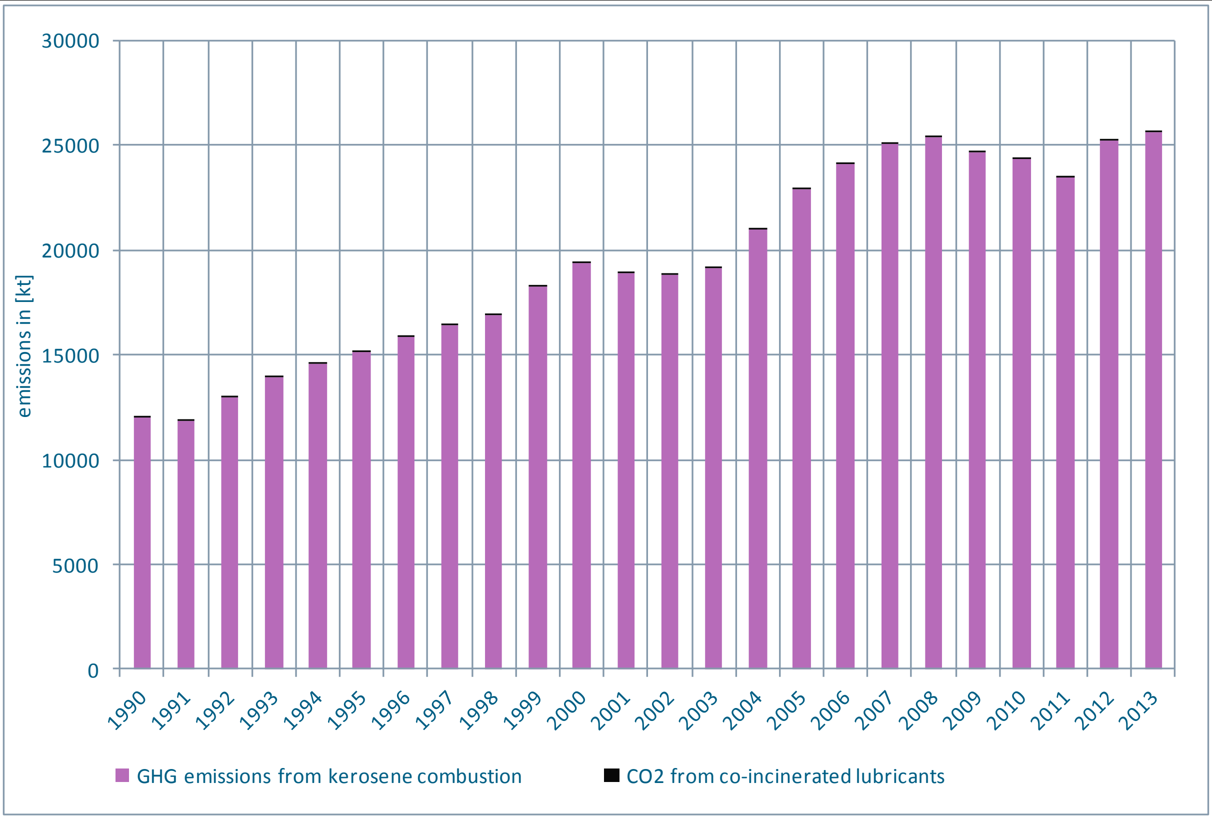


Figure 23: Development of GHG emissions from international flights leaving from Germany, 1990-2013

3.2.2.2.2 Methodological issues (1.D.1.a)

Since German energy statistics do not break annual fuel quantities down by international and domestic aviation, that breakdown is carried out after the fact, on the basis of national air transports' annual shares of total kerosene inputs, a total calculated, using a Tier 3 method, within TREMOD-AV (IFEU & ÖKOINSTITUT, 2014). Avgas consumption is reported separately, and solely for domestic aviation. It does not enter into calculation of the split factor.

International aviation's so-determined shares of the kerosene quantities listed in the National Energy Balance (NEB) (AGEB, 2014) and in the official mineral-oil data (*"Amtliche Mineralöldaten"*) of the Federal Office of Economics and Export Control (BAFA) (BAFA, 2014), are as follows:

Table 18: Development of international civil aviation's share of total kerosene consumption

Year	**1990**	**1995**	**2000**	**2005**	**2006**	**2007**	**2008**	**2009**
Share in [%]	83.81	87.65	88.01	90.07	90.26	90.49	90.64	90.70
Year	**2010**	**2011**	**2012**	**2013**				
Share in [%]	91.14	91.52	92.00	92.59				

Additional information relative to the activity data and emission factors used is presented in Chapter 3.2.10.1 on national civil aviation.

3.2.2.2.3 Uncertainties and time-series consistency (1.D.1.a)

Cf. Domestic aviation, Chapter 3.2.10.1.3.

3.2.2.2.4 Category-specific quality assurance / control (1.D.1.a)

Cf. Domestic aviation, Chapter 3.2.10.1.4.

3.2.2.2.5 Category-specific recalculations (1.D.1.a)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

3.2.2.2.6 Planned improvements (category-specific) (1.D.1.a)

Cf. Domestic aviation, Chapter 3.2.10.1.

3.2.2.3 Emissions from international maritime navigation (1.D.1.b)

3.2.2.3.1 Category description (1.D.1.b)

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS (Tier 2)	NS/IS/M	CS / D*
CH_4	CS (Tier 2)	NS/IS/M	CS (M)
N_2O	CS (Tier 2)	NS/IS/M	CS (M)
NO_X, CO, NMVOC, SO_2	CS (Tier 2)	NS/IS/M	CS (M)

* lubricants

The emissions caused by international maritime navigation from German ports are not reported as part of the national overall inventories, and thus they are not included in the key-category analysis.

Since 1984, consumption of heavy fuel oil has been increasing, as high oil prices have pushed up prices for diesel oil, the maritime-navigation sector has grown worldwide and use of diesel engines that can run on heavy fuel oil has increased. Temporary emissions reductions, especially those that occurred in 1992 and 2009, have been / were caused by trade and oil crises.

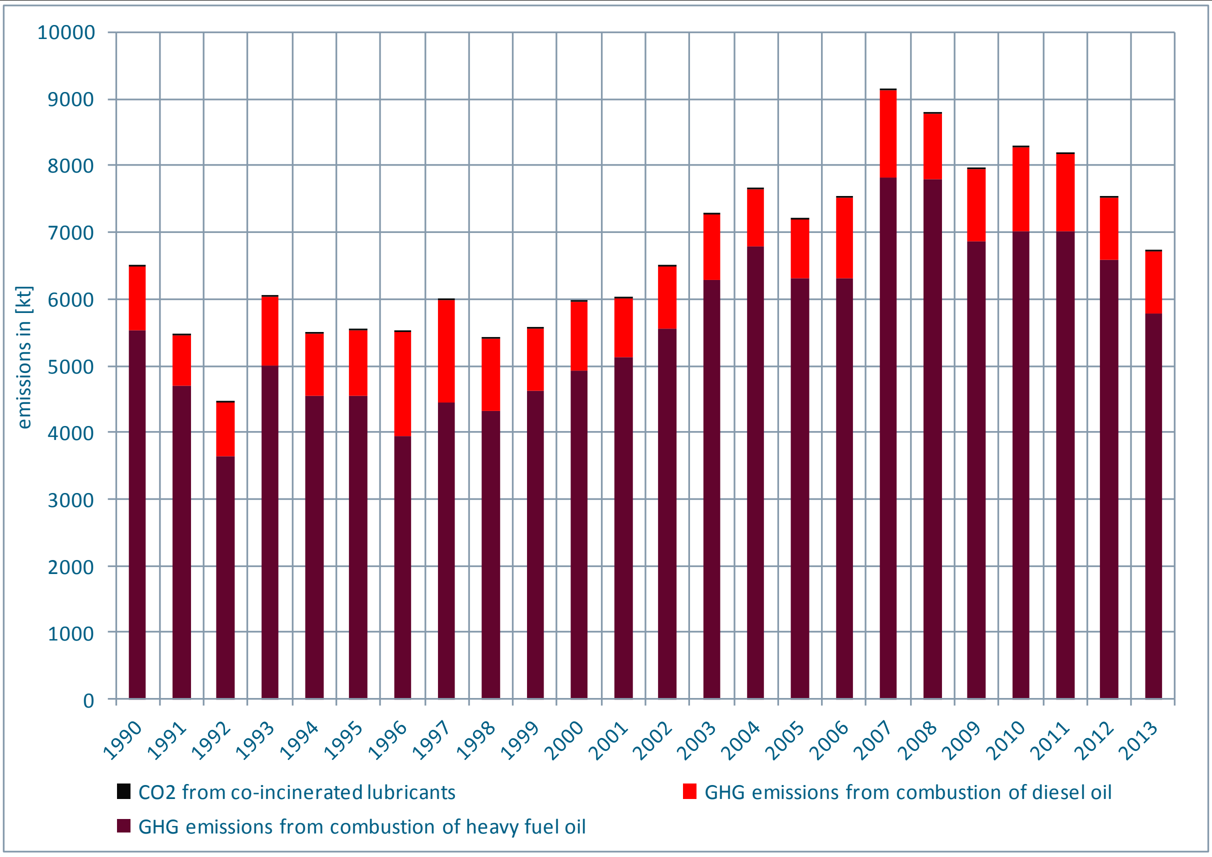


Figure 24: Development of GHG emissions from international maritime transports leaving Germany, 1990 – 2013

3.2.2.3.2 Methodological issues (1.D.1.b)

Germany reports in keeping with Tier 1. This means that emissions are calculated as the product of fuel sales in Germany, country-specific emission factors for CO_2 and default emission factors for CH_4 and N_2O.

In general, the **activity data** for ocean-going ships are taken from (AGEB, 2014). In NEB line 6 (EBZ 6), those balances list deliveries for IMO-registered maritime transports separately, because those deliveries are subject to different taxation, as international marine bunkers.

For years for which an NEB does not become available on time, data published in (BAFA, 2014; for the present context: Table 6j, column: *"Bunker int. Schifffahrt" ("bunkering, international shipping")* are used that enter into the National Energy Balances.

The bunkered quantities, included in these statistics, of ocean-going ships traveling national routes (freight and passengers (1.A.3.d), fisheries (1.A.4.c iii) and military (1.A.5.b iii)) are calculated separately, pursuant to (BSH, 2015), and deducted from the total quantities listed in EBZ 6. The resulting difference is allocated to international maritime navigation from German ports.

In addition, pertinent quantities of co-combusted lubricants, along with the resulting CO_2 emissions, are recorded and reported. Pursuant to (VSI, 2012), it is assumed that the quantities of co-combusted lubricants are equivalent to 0.15 % of the fuel quantities used (cf. the Annex Chapter 19.1.4).

With regard to the pertinent CO_2 **emission factors**, we refer to Chapter 18.7.

The pertinent methane and nitrous oxide emissions are calculated with the emission factors from (BSH, 2015) that are used for national maritime transports. On the other hand, also with regard to co-combustion of lubricants, it is assumed that the pertinent N_2O and CH_4 emissions are already included in the emission factors for the fuels used and thus have to be reported here as IE *(included elsewhere)*.

3.2.2.3.3 Uncertainties and time-series consistency (1.D.1.b)

Cf. Chapter 3.2.10.4.3.

3.2.2.3.4 Category-specific quality assurance / control and verification (1.D.1.b)

Cf. Chapter 3.2.10.4.4.

3.2.2.3.5 Category-specific recalculations (1.D.1.b)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

3.2.2.3.6 Planned improvements (category-specific) (1.D.1.b)

No improvements are currently planned, apart from ongoing routine revisions of the calculation model used pursuant to (BSH, 2015).

3.2.3 Storage

This emissions are taken into account in the framework of the CO_2 Reference Approach.

3.2.4 CO_2 capture and storage (CCS) (CRF 1.C)

At present, CO_2 capture and storage (CCS) technology is still in the research phase in Germany;
some pilot systems are in place.

According to studies carried out by the Öko-Institut e.V. Institute for Applied Ecology in 2014, some 70 kt of CO_2 in have been injected into storage in Germany, on a trial basis. Monitoring of the relevant experimental facilities, with measurements, has found no evidence of leakage of CO_2 from such storage. In the interest of conservative reporting, the so-stored quantities have not been deducted from the German inventory, however. For this reason, any possible leakage has already been taken into account.

3.2.5 Special country-specific aspects

There are no special aspects that would influence reporting.

3.2.6 *Public electricity and heat production (1.A.1.a)*

3.2.6.1 Source-category description (1.A.1.a)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T/2	1.A.1.a Public electricity and heat production	All fuels	CO_2	338,451.0	(27.76%)	328,385.1	(35.12%)	-3.0%
L/-	1.A.1.a Public electricity and heat production	All fuels	N_2O	2,407.5	(0.20%)	2,546.3	(0.27%)	5.8%
-/T/2	1.A.1.a Public electricity and heat production	All fuels	CH_4	172.2	(0.01%)	2,230.2	(0.24%)	1195.4%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	Tier 2	NS	CS
N_2O	Tier 2	NS	CS
NO_X, CO, NMVOC, SO_2	CS	NS	CS

The category *Public electricity and heat production* is a key category for CO_2 emissions in terms of level, trend and Tier 2 analysis. For CH_4 emissions, it is a key category in terms of trend and of Tier 2 analysis, and for N_2O emissions, it is a key category in terms of level.

Under category 1.A.1.a, "Public electricity and heat production", the CSE includes district heating stations and electricity and heat production of public power stations. Plants that feed electricity produced from biomass into the public grid are also assigned to category 1.A.1.a.

Some 101 GW of net bottleneck capacity were in place in the public electricity generating sector in 2013. Of this amount, about 70 GW were operated with fossil fuels or with transformation products of fossil fuels. As a group, all fossil-driven plants generated some 325 TWh of electrical work. This corresponds to about 75 % of all public electricity generation (about 463 TWh). About 278 TWh of electricity were generated solely with lignite and hard coal.

In 2013, combined heat and power (CHP) stations contributed net electricity production of about 50 TWh, and net heat production of 97 TWh, to the public energy supply. The district-heat supply is supplemented with heat from heat-only boiler stations that are normally run in peak-load operation. (*Statistisches Bundesamt (Federal Statistical Office),* 2013a).

The following figure presents an overview of development of CO_2 emissions in category 1.A.1.a:

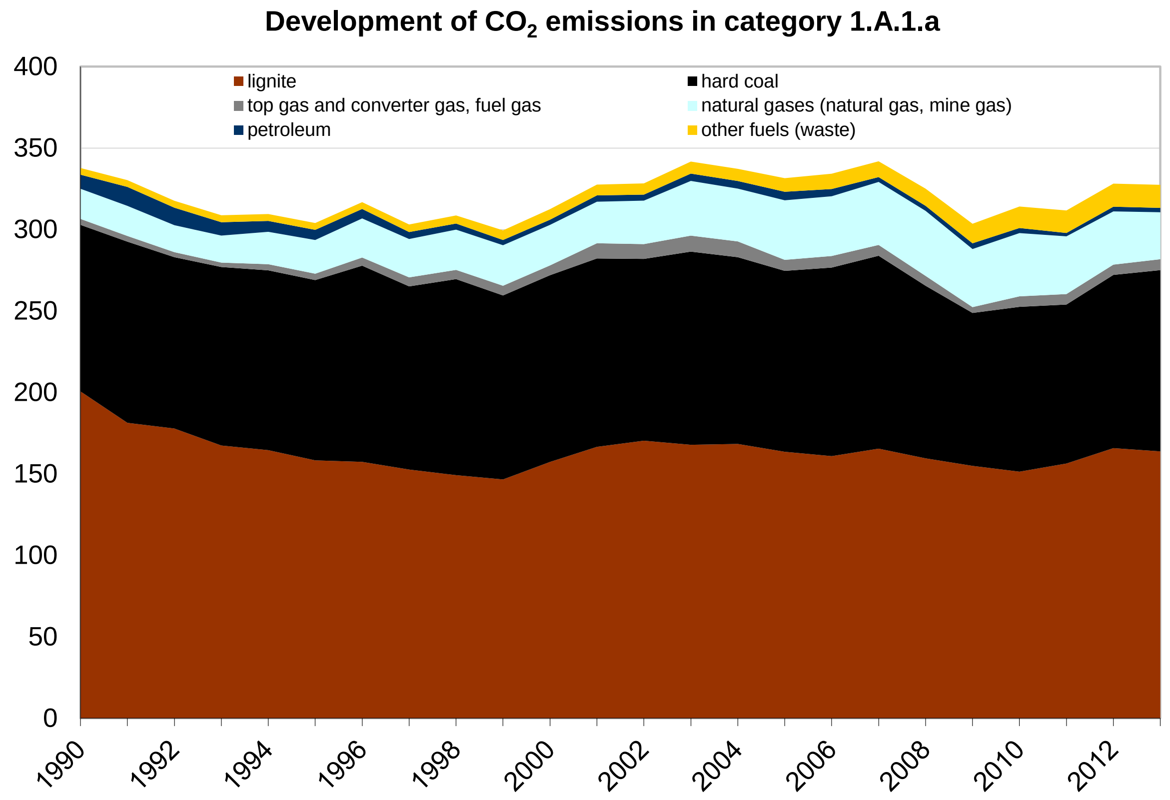


Figure 25: Development of CO_2 emissions in category 1.A.1.a (in millions of t)

Overall, emissions until 1999 show a falling trend, due primarily to closure of four lignite-fired installations in the new German Länder. Thereafter, a number of installations were replaced. As of 2000, then, the newly installed capacities, in the category of lignite-fired power stations, exceeded those of the decommissioned power stations, and thus emissions began increasing again. In 2012, and once again, several new power-station units went online, and this led to further increases in emissions from lignite. Nonetheless, overall emissions from lignite-based electricity generation are considerably below the corresponding emissions level in 1990.

In the main, the emissions trend is shaped by the development and structures of the electricity generation installations involved, since those installations account for the majority of the pertinent emissions. From 1990 through 1993, electricity consumption decreased, as a result of the collapse of industry in the new German Länder. From 1994 until 2007, a marked increase in electricity consumption occurred in all sectors, sparking increases in electricity production. As a result, emissions from electricity production also increased. In addition, electricity exports increased. Those exports begin showing up in the overall balance as of 2003. The increasing trend has been tempered by considerable increases – in comparison to the corresponding levels in 1990 – in use of natural gas, by improvements in power stations' efficiency and by increasing electricity generation via renewable energies.

In 2007, particularly large quantities of coal were used for electricity generation, in keeping with low prices for emissions certificates. Thereafter, beginning in 2008, a temporary marked emissions decrease occurred, as a result of increased use of nuclear power, natural gas and renewable energies. In 2009, the financial and economic crisis occurred, also affecting the public energy supply. By 2010, emissions increased again, as a result of economic recovery. As seen via the relevant time series, hard-coal-fired power stations show higher fluctuations in fuel inputs than lignite-fired power stations do. The reason is that they, in contrast to lignite-fired power stations, are operated primarily in the medium-load range, where they respond more markedly to fluctuations in demand. What is more, they are dependent on import prices. Furthermore, as of the mid-1990s sectoral shifting occurred, from industry (1.A.1.c and 1.A.2.g) to the public electricity supply (1.A.1.a), as more and more operators reported their data in the public electricity supply category. In 2012, the classification for another major company in the hard-coal mining sector (1.A.1.c) shifted to the public electricity supply (1.A.1.a), and this led to a significant shift of emissions between the two sectors. Another reason for the emissions increase from hard-coal-fired power stations in category 1.A.1.a is that world-market prices for hard coal have fallen considerably since 2012. In addition, natural gas prices have increased at the same time, and this has tended to shift the fuel mix in favour of hard coal. Petroleum plays only a minor role in Germany's electricity supply. It is used primarily for auxiliary and supplementary firing in coal-fired and waste-to-energy CHP power stations, as well as for peak-load generation. Use of petroleum in these roles has dropped by more than half since 1990. In the crisis year 2009, when petroleum became considerably cheaper than natural gas, use of petroleum for peak-load generation increased again somewhat. Since then, fuel inputs have been decreasing again, and thus emissions from use of petroleum have been decreasing as well.

Use of natural gas for electricity generation has increased markedly since 1990. That trend has not led to an equivalent emissions increase, however, since the specific CO_2 emissions of natural gas are considerably lower than those of coal. The significant increase in natural gas use seen since 2005 is due especially to the commissioning of a considerable number of major gas and steam turbine power stations and medium-sized gas-turbine power stations. What is more, natural gas is increasingly being used as balancing energy for electricity generation with fluctuating renewable energies. Use of natural gas for electricity generation has been decreasing since 2010. By 2013, gas consumption even fell considerably below its level in 2005. This trend is due primarily to high natural gas prices.

Since 1990, waste inputs in waste-incineration plants and for co-incineration have also been increasing, as a result of changes in relevant laws. The additional emissions resulting from increased waste combustion have reduced methane emissions from landfills. Use of blast furnace gas and basic oxygen furnace gas for electricity generation depends on production of those gases in the steel industry, and thus is subject to economic fluctuations. In addition, operators of relevant facilities are free to report, in the framework of statistical surveys, either in the context of industry or as part of the public supply. Overall, changes in sectoral classification repeatedly occur in connection with all fuels.

In 2010, electricity generation with nearly all fossil fuels increased – sharply, in some cases – as a result of economic recovery, and this led to increased CO_2 emissions. Emissions continued to increase until 2013. This can be explained as the result of a high export surplus. What is more, it has resulted as nuclear power generation has decreased, and been replaced – in part – with fossil-fired power generation. Cold winters have been another reason why CO_2 emissions increased in 2010, 2012 and 2013. The resulting increased demand for heat led to higher fuel inputs in district heating stations. In 2013, emissions remained stable nonetheless. While construction of additional hard-coal-fired power stations has led to an emissions increase, CO_2 emissions have decreased slightly overall, since old lignite-fired power stations have been decommissioned. Increased electricity generation in new, more-efficient installations has slightly decreased emissions from lignite use. In addition, emissions from natural gas use have decreased considerably, as a result of continuing high prices for natural gas. A new increase in electricity generation from renewable energies has also helped to reduce emissions, even though gross electricity generation increased slightly over the previous year.

The trend for the greenhouse gas N_2O is determined primarily by coal use. Since no measures are known to be in place for reducing N_2O emissions in energy generation installations, the decreasing trend seen since 1990 is due to reductions in coal consumption, and the increase in coal-fired electricy generation that has occurred since 2012 has led to increases in N_2O emissions.

CH_4 emissions, by contrast, have been increasing since 1990. The considerable increases in biogas use since 2003 have played an especially noticeable role in this trend. Biogas is used primarily in combustion engines that have high specific methane emissions.

3.2.6.2 Methodological issues (1.A.1.a)

Activity data

In the "Balance of Emissions Sources" model, the energy inputs listed in the Energy Balance are divided among several time series, with the help of statistical data. The aim of the calculations is to produce a database that is adjusted to the special technical characteristics of electricity and heat production. As a result, fuel-specific and technology-specific emission factors can be applied to the relevant activity data.

In 2014, the Federal Environment Agency (UBA) developed a procedure for taking account of known efficiencies (with the help of the UBA's power-station database) in calculations. This was done in order to make it possible to calculate use of natural gas and light heating oil for electricity and heat generation, in gas turbines, gas-and-steam (combined cycle) systems, steam turbines and gas engines. As a result, fuel inputs can now be calculated via the electricity-generation data for the aforementioned installation types as shown in energy statistics.

In the now-available final 2012 Energy Balance, mini-CHP systems are now reported as feeders into the public grid. Consquently, emissions from combustion of natural gas, and of light heating oil, in these installations are reported in category 1.A.1.a. The fuel inputs for heat generation are reported in category 1.A.4. Since the installations lie below the relevant statistical cut-off thresholds, additional data sources had to be used for this purpose. For example, analyses of sales of engine manufacturers were carried out, and the resulting data were checked by comparison with pertinent invoicing pursuant to the German Combined Heat and Power Act (KWK-Gesetz). Since relevant data are available only for the years 2012 and 2013, inconsistencies can occur in the IEF, especially that for methane.

For the 2006 report, the activity data for the new German Länder for the year 1990 were revised and substantiated in the framework of a research project (FKZ 205 41 115 / sub-project A, "Revision and Documentation of Fuel Inputs for Stationary Combustion System in the new German Länder for the year 1990").

In the case of electricity and heat generation in waste incineration plants of public power stations, and of heat generation in waste incineration plants of public district heating stations, the pertinent activity data for household and municipal waste, and for industrial waste, are taken both from the Energy Balance and from the waste statistics of the Federal Statistical Office (*STATISTISCHES BUNDESAMT*, FS 19 Reihe 1).

To date, the waste quantities listed in both energy statistics and the Energy Balance have been considerably lower than those given by the waste statistics of the Federal Statistical Office (*STATISTISCHES BUNDESAMT*, FS 19 Reihe 1). The quality of the data provided by energy statistics has increased considerably in recent years. Such statistics now differentiate fuel data in a way that makes it possible, via calculation, to separate out figures for solid biomass (especially waste and scrap wood), biogenic gases, sewage sludge and waste heat. Industrial waste appeared as a fuel category in energy statistics for the first time in 2008. To ensure that all waste-related fuel inputs are taken into account as completely as possible, i.e. to close the gap that emerges with respect to energy statistics, it is necessary to make use of additional data from waste statistics.

As of the NIR 2006, the fossil and biogenic fractions of household / municipal waste are listed separately, in a ratio of 1/1. The fossil/biogenic composition of industrial waste varies in keeping with the type of facility involved. As a result, the biogenic fractions for co-combustion in lignite-fired and hard-coal-fired power stations, and for electricity and heat generation in public utilities' power stations fired with substitute fuels, are listed separately.

The existing assumptions relative to the biogenic fraction of sewage sludge have been retained.

The activity data for other fuels are taken directly from the Energy Balance. Where pertinent statistical indications or experts' assessments are available, fuel inputs are additionally divided into two size classes (combustion systems smaller and larger than 50 MW). The dividing line between these two categories is based on legal regulations pertaining to licensing of combustion systems in the Federal Republic of Germany.

As of the NIR 2011, CO_2 emissions from top-gas combustion in public power stations are reported in category 1.A.1.a. The following table provides an overview of relevant emissions from top-gas use, for the entire time series since 1990.

Table 19: CO_2 emissions from top-gas combustion in public power stations

[Millions of t of CO_2)									
1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
3.244	3.291	3.015	2.631	3.647	3.764	4.816	5.305	5.465	5.808
2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
5.956	9.284	9.030	9.766	9.640	6.738	7.086	6.370	5.851	3.425
2010	**2011**	**2012**	**2013**						
6.276	6.258	6.080	6.462						

Emission factors

Since CO_2 emissions depend on fuel quality, CO_2 emission factors are calculated and used on an overaching, inter-sectoral basis. A detailed description of the relevant procedures, and a list of the factors used, is presented in the Annex, Chapter 18.7.

The underlying data for the emission factors used for all other greenhouse gases and precursor substances is provided by the report on the research project "Ermittlung und Evaluierung von Emissionsfaktoren für Feuerungsanlagen in Deutschland für die Jahre 1995, 2000 und 2010" ("Determination and evaluation of emission factors for combustion plants in Germany for the years 1995, 2000 and 2010"; RENTZ et al, 2002). The values for the intermediate years 1996 - 1999 and 2001 - 2009 are obtained via linear interpolation. That project, along with the linear interpolation for the intermediate years, has also provided the underlying data for the emission factors presented in Chapters , 3.2.7, 3.2.8 and 3.2.9, where the factors include power stations, gas turbines and boilers for generation of steam and hot/warm water. The research project was carried out by the Franco-German Institute for Environmental Research (Deutsch-Französisches Institut für Umweltforschung – DFIU) at the University of Karlsruhe, and it was completed at the end of 2002. The project aim was to determine and evaluate representative emission factors for the main air pollutants produced by combustion systems in Germany that are subject to licensing requirements, and to do so for the years 1995, 2000 and 2010. The procedure for achieving that aim consists primarily of analysing and characterising the relevant emitter structures, and the pertinent emission factors, for the year 1995, and then of adequately carrying that data forward for the years 2000 and 2010. The procedure systematically determines emission factors for the substances SO_2, NO_X, CO, NMVOC, particulates and N_2O. Furthermore, it differentiates between 12 coal fuels, 4 liquid fuels, 7 gaseous fuels and firewood. In addition, the available data relative to emission factors of other substances are also compiled; these other substances include PAH, PCDD/F, As and Cd for combustion systems subject to licensing requirements, and CH_4 for gas turbines and combustion systems subject to licensing requirements that fall under the TA Luft. Annex 3 (Chapter 19.1.2) discusses the procedure used in the research project.

In connection with a major research project that began at the end of 2008 and was completed in 2011 (FICHTNER et al. 2011), we have begun updating the described database for emission factors (except for that for CO_2). The reference year for the proposed values is 2004. On that basis, emission factors are being predicted for the years 2010, 2015 and 2020. As described in the reports for 2012, 2013 and 2014, numerous emission factors in the Central System of Emissions (CSE) have been updated on the basis of the research results. In Germany, N_2O is monitored only in exceptional cases; for this reason, no relevant data from regular measurements are available. On the other hand, relevant emissions behaviour in combustion of hard coal and lignite, especially in fluidised-bed combustion, has been specifically studied, especially in the 1990s. The FICHTNER et al 2011 project has reviewed and updated the values used to date. Table 20 shows the results for large installations of public power stations (with thermal outputs from combustion of 50 megawatts or more), while Table 21 shows the results for smaller installations of the energy sector and of industry. These factors have been used as a basis for calculating the category-specific emission factors for the CSE.

Table 20: Technological emission factors for nitrous oxide from large combustion systems

Fuel / combustion technology	N_2O emission factor [kg/TJ]
Public power stations:	
Hard coal / dry firing	1.0
Hard coal / slag tap firing	1.9
Lignite / dry firing	3.5
Liquid fuel / boiler firing	1.0
Natural gas / boiler firing	0.5

Fuel / combustion technology	N_2O emission factor [kg/TJ]
Industrial power stations, industrial boilers and district heating stations:	
Hard coal / dry firing	1.0
Hard coal / slag tap firing	2.0
Hard coal / fluidised bed combustion	20
Hard coal / grate firing	4.0
Lignite / dry firing	3.4
Lignite / fluidised bed combustion	8.0
Lignite / grate firing	3.5
Liquid fuel / boiler firing	1.0
Natural gas / boiler firing	0.5
Gas turbines and gas and steam turbine plants:	
Natural gas	1.7
Light heating oil	2.0
Waste incineration plants	1.2

Table 21: Technological emission factors for nitrous oxide from systems < 50 MW furnace thermal output

Fuel / combustion technology	N_2O emission factor [kg/TJ]
Boiler firing with:	
Hard coal	10.0
Lignite	10.7
Biomass	3.0
Light heating oil	1.1
Heavy heating oil	3.0
Natural gas	0.6
Gas turbines and gas and steam turbine plants:	
Natural gas	1.7
Light heating oil	2.0

Table 22: Methane emission factors for combustion systems with at least 50 MW furnace thermal output and for gas turbines

Facility type	Fuel	CH_4 emission factor [kg/TJ]
Combustion systems ≥ 50 MW furnace thermal output	Hard coal	1.0
	Lignite	0.63
	Heating oil, heavy	4.1
	Heating oil, light	3.3
	Natural gas	2.0
Gas turbines (including gas-and-steam systems)	Heating oil, light	8.0
	Natural gas	10.925
Combustion engines	Natural gas	309.0
	Biogases	312.3
Waste incineration		1.8

In a research project carried out by the Institute for Future Studies and Technology Assessment (IZT), "Aufbereitung von Daten der Emissionserklärungen gemäß 11. BImSchV" ("Processing of data in emissions declarations pursuant to the 11th Ordinance on the Execution of the Federal Immission Control Act"), special CH_4 emission factors for gas engines were determined. The average value for natural gas as a fuel, 309 kg/TJ, is markedly higher than the previously used value, 0.3 kg/TJ, which is approximately the same as the value for steam-turbine power stations. With emissions-monitoring data, it was possible to confirm that significant methane leakage occurs via leakage of unburned natural gas. The pertinent measurements can vary considerably, in keeping with the type of engine and engine-maintenance standards involved. For biogas, sewage gas, landfill gas and mine gas, an average CH_4 emission factor of 185 kg/TJ was determined. For biogas, at least, it was possible to confirm that figure with data from emissions monitoring. In light of the lower methane concentrations of biogenic gases, the corresponding factor must be set lower for them than for natural gas.

Most of the emission factors used for waste incineration have been obtained from a research project carried out by the waste-management and recycling firm ATZ, "Review of emission factors for waste incineration" ("Überprüfung der Emissionsfaktoren für die Abfallverbrennung"). The N_2O emission factors have been obtained from a Danish study, "Emissions from decentralized CHP plants 2007". Since the emission factors for other pollutants agree well with those for German waste incineration plants, the relevant N_2O factors may be adopted for purposes of the German inventory. For co-combusted waste, weighted emission factors are used that vary in keeping with the pertinent shares for the various coal types involved.

Information on process-related CO_2 emissions from flue-gas scrubbing (flue-gas desulphurisation) in large combustion systems is provided by Annex 3 in Chapter 19.1.2.2.

3.2.6.3 Uncertainties and time-series consistency (1.A.1.a)

Uncertainties for activity data were determined, for the first time ever, for the 2004 report year (research project FKZ 204 41 132, UBA). The method for determining the uncertainties is described in Annex 2, Chapter 13.6 of the NIR 2007.

Other aspects relative to time-series consistency of activity data are explained in Chapter 18.4 and Chapter 18.6.

The figures for the uncertainty of the CO_2 emission factor, and for the statistical distribution function for that uncertainty, have been estimated by the Federal Environment Agency. The figures are based on the range covered by the carbon contents of the various individual fuels.

The uncertainty of the determined emission factors was evaluated in the framework of the project (mentioned in Chapter 3.2.6.2) of RENTZ et al (2002) and FICHTNER et al (2011).

3.2.6.3.1 Methods for determining uncertainties of emission factors

The uncertainties in emissions data result from several different factors. These include *precision*, which is influenced by chance and systematic errors in the framework of emission measurement, as well as by the completeness of the database with regard to available measurements. Another factor consists of *variability* of emissions. In this area, a distinction must be made between variability in emissions of a single plant, within the period in question (*intra-plant variability*) and differences between the emissions behaviours of the various sources considered (*inter-plant variability*).

Other sources of possible uncertainties can affect calculation of emissions with the help of emission factors. In the framework of IPCC-GPG (2000: Chapter 6), methods – adapted, in each case, to data availability – are proposed:

Where *continuous* measurements have been carried out, uncertainties should be characterised via direct determination of statistical indexes such as standard deviation and the 95%-confidence interval.

In determination of *plant-specific emission factors*, any available local measurements should be used. In addition, any special operational states (start-up and shut-down processes) and load changes should be taken account of, and available measurements should be reviewed for representativeness in light of the relevant plant's emissions behaviour.

In use of *emission factors from the literature*, all of the data-quality information provided by the sources in question should also be used. Furthermore, transferability should be reviewed – to what extent is the emission factor in question representative of the situation in the relevant area being studied? If the factor is not representative, an experts' assessment should be carried out.

In general, use of *experts' assessments* is recommended in cases in which available empirical data do not suffice for quantification. A sample explanation is provided in Annex 3, Chapter 14.1.2.2, of the NIR 2007.

3.2.6.3.2 Result for N_2O

The individual evaluations of the uncertainties for the N_2O emission factors are described in the final report of the research project (FICHTNER et al, 2011). A Monte Carlo simulation carried out by the research contractor yielded percentage uncertainties of up to +/- 50 % for CRF category 1.A.1.a (as well as for categories 1.A.1.b, 1.A.1.c and 1.A.2.f / all other) (remark: values for +/- ranges must be divided by 2; cf. IPCC-GPG (2000: Chapter 6, p. 6.14). In the process, we continue to assume a uniform distribution of uncertainties.

3.2.6.3.3 Result for CH_4

Combustion systems in Germany are not subject to monitoring of CH_4 emissions; for this reason, no systematic-measurement data are available in this area. Consequently, relevant individual data items available in Germany and Switzerland have been relied on. As a result of this database limitation, the research project did not attempt any systematic correlation with categories treated by the project (cf. Chapter 3.2.6.2). The CH_4 emission factors that were determined in the research project FICHTNER et al (2011) for various fuels, and that are used in the present report for combustion and gas-turbine systems (including gas-and-steam systems), have been compiled in Annex 19.1.2.2. As part of an experts' assessment carried out by the research contractor, pursuant to Tier 1 of the IPCC-GPG (2000: Chapter 6), an upper limit of +/- 50 % was estimated for the percentage uncertainty in category 1.A.1a (as well as in categories 1.A.1b, 1.A.1c and 1.A.2f / all other); in the process, we assume a uniform distribution of uncertainties – as was the case for N_2O.

3.2.6.3.4 Time-series consistency of emission factors

The emission factors for N_2O were determined in the framework of a research project (FICHTNER et al 2011), for the year 2004 (reference year). The research project saw no indications of changes over time in the individual emission factor. Earlier assumptions to the effect that at least the values for gas turbines might vary over time were not confirmed. For this reason, we have used constant values in each time series, for the period 1995 to 2013, and assumed that the values are valid predictive values for the period through 2020.

In this light, the time series for N_2O between 1995 and 2013 must be assessed as consistent overall. The time series of CH_4 emission factors for 1995 to 2013 were also reviewed and assessed as internally consistent.

In the NIR 2009, we reported on the period from 1990 to 1994.

To ensure time-series consistency, the CH_4 emission factors determined for combustion-engine systems were retroactively applied for the period back to 1990. Methane leakage is likely to have been higher in the early 1990s than it is with modern engine systems. Too little relevant measurement data is available for that period, however.

For most biogenic fuels, statistical fuel-input data are available only for the period since 2003. As a result, it is not possible to provide a consistent time series, for the period since 1990, for such fuels. That limitation affects only the trend for CH_4 emissions, which increases sharply as of the year 2003.

3.2.6.4 Category-specific quality assurance / control and verification (1.A.1.a)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

To document its quality-assurance measures in preparation of Energy Balances, the Working Group on Energy Balances (AGEB) submits pertinent quality reports to the Federal Environment Agency (UBA) (cf. Chapter 18.4.1). Since 2012, the AGEB has carried out systematic comparisons of the estimated Energy Balance of year x-1 (provisional) and the Energy Balance of year x-2 (final); this was done for the first time for the report year 2010 (cf. Chapter 18.4.1). In addition, revisions of the Energy Balances as of 2003 have been archived, and published in the Internet[26].

Quality assurance for official statistics is carried out via an internal quality system. That system's quality reports are available for inspection within the Internet publications of the *Federal Statistical Office*.

In addition to these measures, the AGEB plays a role in the annual review process, and regular exchanges take place with the AGEB in the framework of an annual meeting to which the Federal Environment Agency (UBA) invites all institutes that take part in preparing the Energy Balance. At such meetings, methodological issues are discussed, and general exchanges take place for the purposes of clarifying data-collection issues and verifying data. All of this is done in light of experience gained in inventory preparation and inventory review.

General measures for assuring the quality of emission factors for combustion plants, as applied in the framework of the research projects RENTZ et al (2002) and FICHTNER et al (2011), are outlined in the methods description in Annex 3, Chapter 19.1.2.1 (after Figure 85). Their results were reported in the NIR 2005.

3.2.6.5 Category-specific recalculations (1.A.1.a)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

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[26] AG Energiebilanzen (Working Group on Energy Balances): explanations relative to revision of the Energy Balances 2003 – 2006; URL: http://www.ag-energiebilanzen.de/files/revision_der_energiebilanzen_2003_bis_2009_05.pdf;
Energiebilanzen für die Bundesrepublik Deutschland – Methodische Änderungen ab 2010 und Revisionen 2003 bis 2009 ("Energy Balances for the Federal Republic of Germany – methodological changes as of 2010, and revisions, 2003 through 2009"); http://www.ag-energiebilanzen.de/index.php?article_id=7&clang=0
(checked on 7 October 2013)

3.2.6.6 Planned improvements (category-specific) (1.A.1.a)

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

3.2.7 Petroleum refining (1.A.1.b)

3.2.7.1 Source-category description (1.A.1b)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T/2	**1.A.1.b Petroleum Refining**	**All fuels**	**CO_2**	**20,165.6**	**(1.65%)**	**17,993.6**	**(1.92%)**	**-10.8%**
-/-	1.A.1.b Petroleum Refining	All fuels	N_2O	100.4	(0.01%)	54.6	(0.01%)	-45.6%
-/-	1.A.1.b Petroleum refining	All fuels	CH_4	16.1	(0.00%)	12.9	(0.00%)	-19.8%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	Tier 2	NS	CS
N_2O	Tier 2	NS	CS
NO_X, CO, NMVOC, SO_2	CS	NS	CS

The category *Petroleum refining* is a key category for CO_2 emissions in terms of emissions level and trend and of Tier 2 analysis.

The figures given above apply for refinery power stations (part of category 1.A.1.b).

The crude oil distillation capacity of German petroleum refineries totalled around 104 Mt in 2013. In that period, 93 Mt of crude oil, along with 11 Mt of intermediate products, were input for processing. Production of petroleum products totalled 101 Mt, of which about 50 Mt consisted of fuels, about 23 Mt consisted of heating oils, about 7.8 Mt consisted of naphtha and about 20.2 Mt consisted of other products. (MWV, 2014, Tab PRE1.1, Tab 4, Tab 5j).

Petroleum processing plants operate power stations with electrical output of about 1.4 GW. In 2012, those power stations generated 6.8 TWh of electricity. (*Statistisches Bundesamt (Federal Statistical Office),* 2012c, WZ 192 Mineralölverarbeitung (petroleum processing).

Under category 1.A.1.b, Petroleum refining, the CSE lists the sub-categories "refinery bottom-heating systems" and "electricity and heat production of refinery power stations".

The following figure provides an overview of emissions trends in category 1.A.1.b:

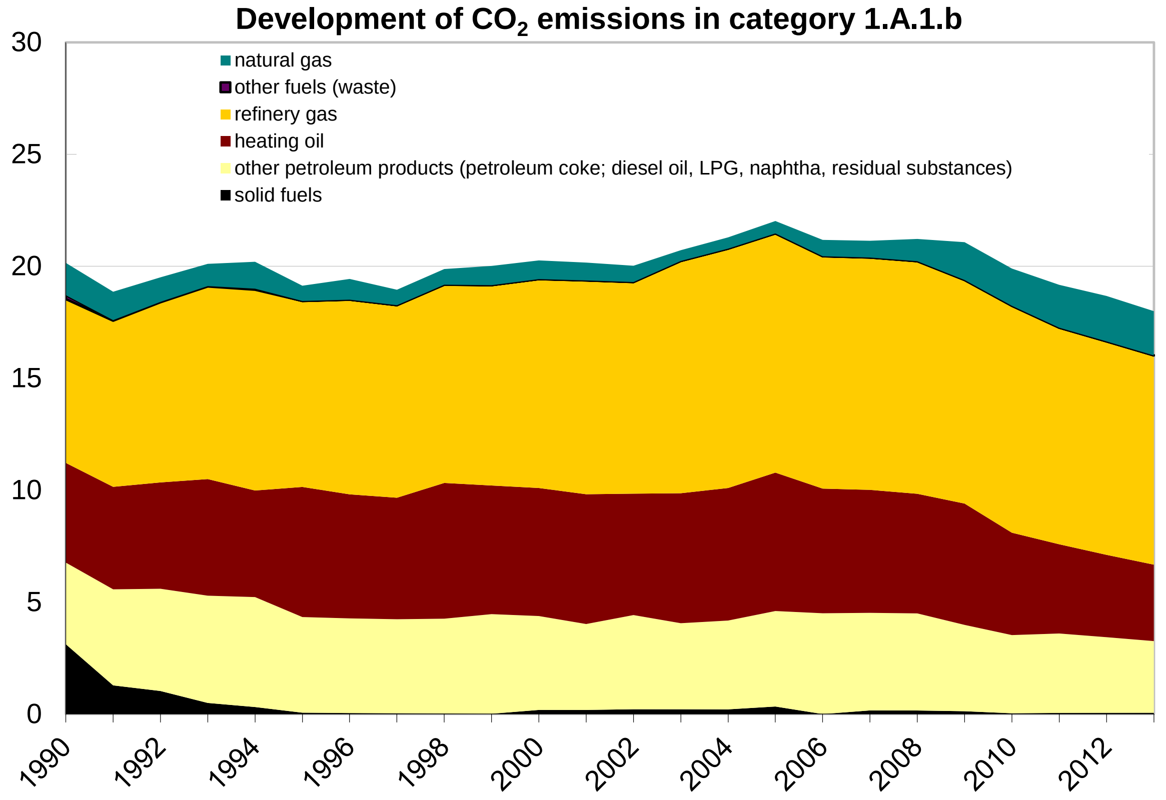

Figure 26: Development of CO_2 emissions in category 1.A.1.b (in millions of t)

In the early 1990s, raw lignite was still being used in the new German Länder. Now, only a small quantity of coke-oven gas is reported under solid fuels in this category. Overall, the emissions show a slightly increasing trend through 2005. Thereafter, they decrease again. While some relevant installations have been decommissioned since 1990 – although such decommissioning has taken place on a smaller scale than that seen in the hard-coal and lignite mining sectors – production increased nevertheless. And while installation efficiencies were improved, increased production of lighter petroleum products, and intensified ultra-hydrodesulphurisation, initially led to increases in specific fuel consumptions. The emissions fluctuations that have occurred over the years can be explained as the result of differences in production quantities. The maximum production of petroleum products to date, totalling 123.6 million t, occurred in 2005. The pertinent emissions were correspondingly high. Thereafter, production decreased, to a level of 103.3 million t of petroleum products in 2011, and emissions decreased as a result. The market situation for oil refineries is still difficult, due to overcapacities – especially in Europe. One German refinery terminated its operations in 2010, thereby making it possible to increase capacity utilisation somewhat at the other German refineries. Emissions decreased in 2012, even though the overall production quantity increased slightly. This trend is due to increased use of natural gas, which has lower emissions, and to improvements in plant efficiency. The trend continued in 2013. Total production of petroleum products decreased in 2013 to 101.4 million t, making the emissions reduction in that year even more pronounced.

3.2.7.2 Methodological issues (1.A.1.b)

Activity data

All Energy Balance data relative to production of petroleum products have been obtained from the Official Mineral Oil Statistics. The Mineral Oil Statistics provide a comprehensive picture of petroleum imports, of transformation inputs in refineries and of refineries' own consumption. To ensure consistency, reporting in this area adheres to the Mineral Oil Statistics in terms of structure. It thus uses the Statistics' definition of "refineries". In energy statistics, other types of companies and plants, such as companies that process coal and refineries for waste oil and lubricants, also report under industrial sector (Wirtschaftszweig) 19.2 Petroleum processing (Mineralölverarbeitung). Such installations are reported in category 1.A.1.c. Consequently, only crude oil processing is reported in category 1.A.1.b.

For purposes of reporting on emissions from crude oil refineries, the relevant plants are subdivided into refinery power stations and bottom-heating systems. The activity data for refinery-process bottom heating are obtained by subtracting fuel inputs in refinery power stations (as taken from the energy statistics) from refineries' own energy consumption (as taken from the Official Mineral Oil Statistics). This distinction plays no role in calculation of the pertinent greenhouse-gas emissions. The distinction is important, however, with regard to calculation of emissions of precursor substances and of other air pollutants, since the relevant plants differ in their emissions behaviour.

The figures for own consumption of petroleum coke that are listed in the Official Mineral Oil Statistics represent coke burn-off in catalyst regeneration within the plants. Since the basis on which the plant operators calculate their petroleum-coke inputs is not known, it is not possible to obtain a suitable CO_2 emission factor. For the years 2005 through 2013, it has been possible to determine emission factors from data, available via emissions trading, on total emissions from coke burn-off in catalyst regeneration and from plants' own consumption of petroleum coke. As a result, therefore, it has been possible to determine emissions from coke burn-off in catalyst regeneration precisely, for the relevant current years, and in agreement with in the data available from emissions trading. To make it possible to determine the pertinent factors retroactively, back to 1990, first a specific factor was defined that is oriented to the capacity of the reforming plants involved. Various reviews have found that this procedure comes closest to the underlying reality, since the available statistics do not include data on inputs and outputs of the reformers and of fluid catalytic cracking (FCC) plants. The result obtained is that emissions from coke burn-off in catalyst regeneration were considerably lower in 1990 than they were in the current year. This seems plausible, since processing of heavy petroleum products has increased considerably since 1990.

For the years 1990 – 1993, no data on own consumption of petroleum coke are available for the new German Länder. As a result, the pertinent data for those Länder had to be calculated from the emission factor determined from the emissions-trading data.

Since virtually all of oil refineries' emissions result from combustion processes, the refineries' emissions are reported in category 1.A.1.b. In one exception, fugitive emissions from production of calcined petroleum coke are reported in category 1.B.2.a.iv.

Emission factors

A detailed description of the relevant procedures, and a list of the CO_2 emission factors used, is presented in the Annex, Chapter 18.7.

The emission factors for N_2O, CH_4 and precursor substances for refinery power stations have been taken from the research projects RENTZ et al (2002) and FICHTNER et al (2011). A detailed description of the procedure is presented in Chapter 3.2.6.2 and in Chapter 19.1.2.1 in Annex 3. The cited project does not provide any emission factors for the bottom-heating systems that supply process heat. To compensate for this gap, for bottom-heating systems the same values for N_2O and CH_4 were chosen that are used for refinery power stations.

3.2.7.3 Uncertainties and time-series consistency (1.A.1.b)

Uncertainties for the activity data were determined for the first time in the 2004 report year (research project 204 41 132, UBA). The method for determining the uncertainties is described in Annex 2, in the Chapter "Uncertainties in the activity data of stationary combustion systems" (Chapter 13.6 of the NIR 2007).

3.2.7.3.1 Result for N_2O

The results of Chapter 3.2.6.3.2 apply mutatis mutandis.

3.2.7.3.2 Result for CH_4

The results of Chapter 3.2.6.3.3 apply mutatis mutandis.

3.2.7.3.3 Time-series consistency of emission factors

The results of Chapter 3.2.6.3.4 apply mutatis mutandis.

3.2.7.4 Category-specific quality assurance / control and verification (1.A.1.b)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

With regard to refineries, comparisons with data from the British inventory were carried out. The two countries' refinery capacities are roughly similar in size. To enhance comparability, numerous indicators were defined, for factors such as transformation inputs and production data, in addition to emissions-relevant own consumption. Comparisons of the indicators show excellent agreement.

For further information on quality assurance, cf. CRF 1.A.1.a (Chapter 3.2.6.4).

With regard to emission factors, the results of Chapter 3.2.6.3 apply mutatis mutandis.

3.2.7.5 Category-specific recalculations (1.A.1.b)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

3.2.7.6 Planned improvements (category-specific) (1.A.1.b)

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

3.2.8 *Manufacture of solid fuels and other energy industries (1.A.1.c)*

3.2.8.1 Source-category description (1.A.1.c)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T	**1.A.1.c Manufacture of Solid Fuels and Other Energy Industries**	**All fuels**	**CO_2**	**65,289.0**	**(5.36%)**	**10,267.5**	**(1.10%)**	**-84.3%**
-/-	1.A.1.c Manufacture of Solid Fuels and Other Energy Industries	All fuels	N_2O	659.2	(0.05%)	150.1	(0.02%)	-77.2%
-/-	1.A.1.c Manufacture of Solid Fuels and Other Energy Industries	All fuels	CH_4	92.0	(0.01%)	13.9	(0.00%)	-84.9%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	Tier 2	NS	CS
N_2O	Tier 2	NS	CS
NO_X, CO, NMVOC, SO_2	CS	NS	CS

The category *Manufacture of solid fuels and other energy industries* is a key category, in terms of both emissions level and trend, of CO_2 emissions.

The above figures refer to power stations, and to other boiler furnaces for production of steam and hot/warm water, in category 1.A.1.c.

Category 1.A.1.c includes hard-coal and lignite mining, coking and briquetting plants and extraction of crude oil and natural gas. In 2013, the German hard-coal mining sector extracted 7.6 Mt of usable hard coal (10.8 Mt in 2012) (Statistik der Kohlewirtschaft 2013). Coke production in 2013 totaled 8.27 Mt (2012: 8.05 Mt) (Verein deutscher Kokerei-Fachleute VdKF – cf. http://www.vdkf-ev.de/content/aktuelles/aktuelles_produktkennzahlen.asp 18). Production of hard-coal briquettes was discontinued at the beginning of 2008.

In 2013, 182.7 Mt of crude lignite was produced in Germany (ibid.). Combined production of lignite briquettes and other lignite products amounted to about 7.0 Mt (ibid.). Steam for drying of raw lignite, for production of refined lignite products, is obtained from lignite-fired power stations with process-steam extraction (CHP plants). From these plants, steam is drawn off for drying crude lignite for production of lignite products.

In 2013, German production of petroleum totalled 2.6 Mt (MWV, 2014), while production of natural gas reached about 10.7 Mill kWh Hi (AGEB, 2014). The fuel inputs required for installations' own operations are reported in category 1.A.1.c.

In the CSE, category 1.A.1.c Manufacture of solid fuels and other energy industries includes electricity and heat production in steam-turbine power stations, broken down by hard-coal mining and lignite mining (mine power stations); electricity and heat production in gas turbines, gas engines and diesel engines of all colliery and mine power stations; other heat production in industrial boilers within the transformation sector (not including refineries); and manufacture of hard-coal coke and operation of diesel engines for propulsion purposes in colliery and mine power stations. In reporting, they are broken down into the categories "large combustion systems" and "plants falling under the Technical Instructions on Air Quality Control" (TA Luft).

During the course of 2013, one mine-mouth power plant was decommissioned in the Mitteldeutschland (central German) region; this decreased emissions.

The following figure provides an overview of emissions trends in category 1.A.1.c:

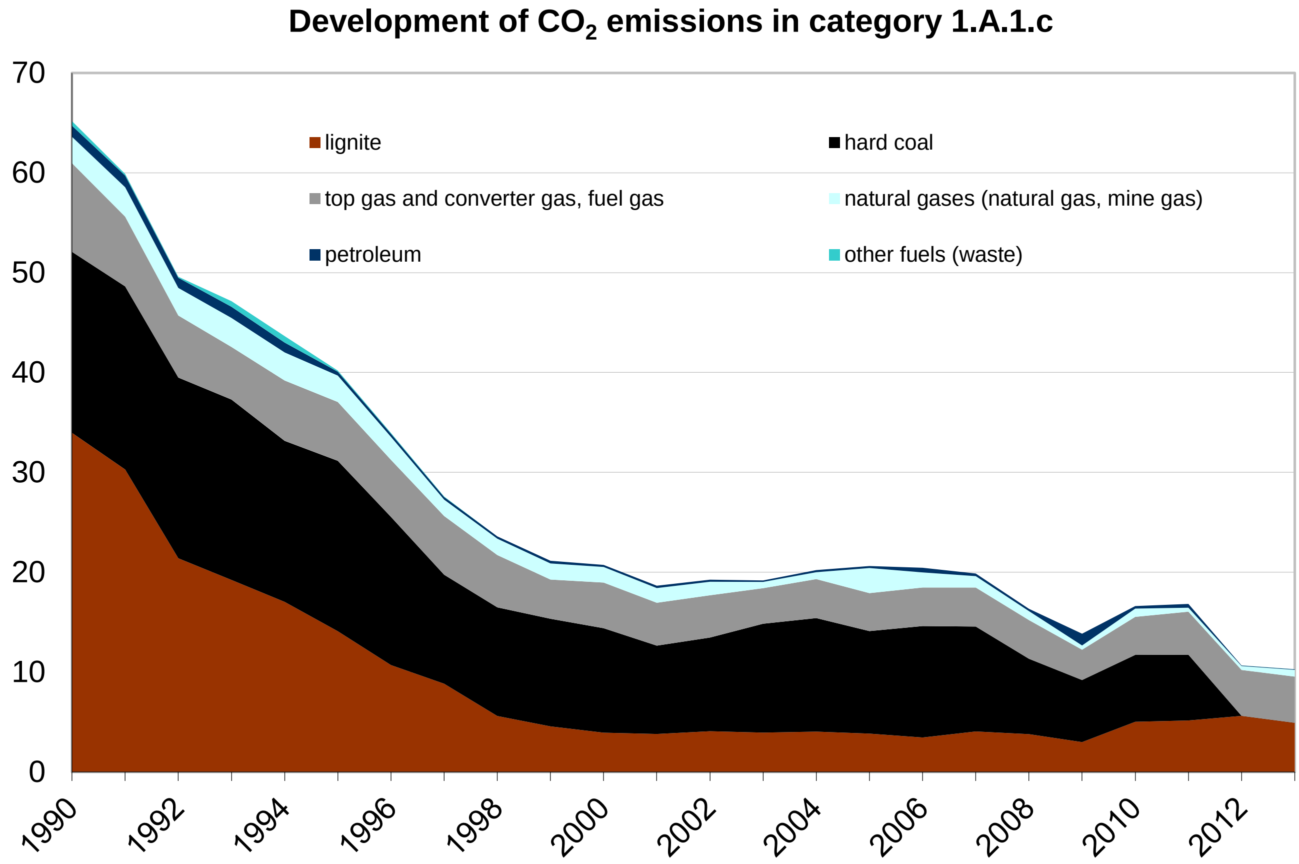

Figure 27: Development of CO_2 emissions in category 1.A.1.c (in millions of t)

The figure clearly shows how sharply emissions in this category have decreased since 1990. The largest emissions decrease occurred in the area of lignite, use of which decreased strongly in the new German Länder from usage levels of the industry of the former GDR. From raw lignite, a range of refined products used to be produced for industry, households and small commercial operations. A comprehensive transition from lignite to other fuels then took place until the end of the 1990s. In a – then considerably reduced – number of industrial plants and commercial operations, use of hard coal, petroleum and natural gas intensified, while coal-burning stoves in homes were replaced with more modern heating systems fired with heating oil and natural gas. As a result, coal briquette and dust production in the new German Länder decreased from nearly 39 million t in 1990 to about 2.6 million t in 1997. Most lignite-processing plants were closed in that period, and thus emissions decreased sharply. As of 1998, energy for drying lignite products in the new German Länder was provided solely via process steam from public power stations. In the old German Länder, improvements in plants' efficiencies, along with reduced production in that area as well, until 2003, reduced emissions. Thereafter, slight increases occurred again, as a result of production increases.

Emissions from use of hard coal in sector 1.A.1.c have been decreasing markedly since 1990. That decrease is due, firstly, to a sharp reduction in hard coal mining; while hard coal production still exceeded 70 million t in 1990, by 2013 it amounted to less than 8 million t. Secondly, the decrease is due to the fact that some installations have shifted, for reporting purposes, from the hard coal mining category to the public electricity supply category, thereby shifting their emissions as well. The power stations remaining in category 1.A.1.c also feed electricity into the public grid.

Beginning in 2010, fuel inputs in the lignite-fired and hard-coal-fired power stations allocated to category 1.A.1.c. increased, as a result of economic recovery and related increased electricity demand. Another explanation for the increased lignite consumption is that some power stations have been taken from the public electricity generation sector and placed in the lignite mining sector. This has led to higher emissions overall.

Use of industrial gases (coke oven gas, blast furnace gas and basic oxygen furnace gas) also decreased until the end of the 1990s. The primary reason for this is that city-gas production was phased out through 1996, in a process involving decommissioning of local gas works. Coke production also decreased markedly. Production of hard coal coke decreased from 19 million t in 1990 to just less than half of that figure in 2008. Production in 2009 amounted to only 6.7 million t, as a result of low steel production. In 2010, then, as the economic situation improved, hard-coal-coke production increased again, to about 8 million t. Production then remained at that level through the year 2013. Consequently, emissions from combustion of blast furnace gas and coke oven gas rose considerably. In 1990, a total of 8 mine coking plants were still in operation. Today, only five coking plants remain in operation, and all belong to the steel industry ("metallurgical coking plants"). Overall, plant closures and efficiency increases have decreased emissions markedly in this sector.

In 2012, several important installations in the hard-coal mining sector were shifted, for reporting purposes, into the public sector. This very markedly reduced emissions in category 1.A.1.c. At the same time, this statistical effect led to an increase of emissions from hard-coal use in sector 1.A.1.a. For all sectors overall, emissions from hard-coal-fired electricity generation increased in 2012.

The slight emissions decrease seen in 2013 is due mainly to the closure of a mine-mouth power plant in the central German lignite-mining district and to decreased fuel inputs in mine-mouth power plants in the Rhineland area. The emissions decrease was only moderate overall, since natural gas inputs for "other energy producers" increased at the same time.

3.2.8.2 Methodological issues (1.A.1c)

The calculation method has been selected on the basis of the latest key-category analysis.

Fuel inputs for electricity production in power stations of the hard-coal and lignite mining sector are listed in Energy Balance line 12, "Industrial thermal power stations". Fuel inputs for heat production in the transformation sector are listed in Energy Balance lines 33-39 and in sum line 40 ("Total energy consumption in the transformation sector").

Fuel inputs for electricity production in power stations of the hard-coal mining sector are determined with the help of figures of the Federal Statistical Office (*STATISTISCHES BUNDESAMT*, 2013c). The activity data for heat production in power stations of the hard-coal mining sector correspond to Energy Balance line 34 "Energy input in collieries and briquette plants of the hard-coal mining sector".

The listed fuel input for electricity production in mine power stations is based on association information (personal communication from DEBRIV, the federal German association of all lignite producing companies and their affiliated organisations). Inputs for heat production, especially for lignite drying for production of lignite products, are not shown in the Energy Balance. Those are calculated from figures for production of lignite products (STATISTIK DER KOHLENWIRTSCHAFT n.y.) and from the specific fuel inputs required for drying (personal communication from DEBRIV, February 2013), listed as "non- Energy-Balance inputs" in the CSE, and reported as such. The data are collected and updated via annual surveys.

The quantities of fuel used for production of hard-coal coke are taken directly from the Energy Balance, line 33 (coking plants). That line includes the coking plants' own consumption. Fuel combustion for bottom-heating systems is the largest emission source in the coking plant sector. In the coking process, fugitive emissions also occur before the coke is quenched, however; these are reported in category 1.B.1.b.

The fuel input for heat production in the other transformation sector is obtained by combining the energy consumption figures in Energy Balance lines 33 to 39 (total energy consumption in the transformation sector). Those figures include mines' own consumption; facilities for petroleum and natural gas production and for processing of waste oil; plants that produce coal products; plants for production and processing of fissile and fertile materials; and wastewater-treatment facilities' own consumption.

As of the 2011 report, CO_2 emissions from top-gas combustion in coking plants are reported in category 1.A.1.c. The following table provides an overview of CO_2 emissions from top-gas use in coking plants, for the entire time series since 1990.

Table 23: CO_2 emissions from top-gas combustion in coking plants

[Millions of t of CO_2)									
1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
5.340	5.251	4.590	4.083	5.066	4.924	4.707	4.969	4.362	3.145
2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
3.652	3.741	3.684	3.029	3.356	3.247	3.281	3.226	3.226	2.500
2010	**2011**	**2012**	**2013**						
3.245	3.895	4.289	4.341						

Revision of the data for 1990, and for the years 1991-1994, for the new German Länder is described in Annex Chapter 19.1.1.

Emission factors

A list of the CO_2 emission factors used, and a description of the relevant methods, are provided in the Annex, Chapter 18.7.

The emission factors for power stations and other boiler combustion for production of steam and hot/warm water, in category 1.A.1.c, have been taken from RENTZ et al (2002) and FICHTNER et al (2011). A detailed description of the procedure is presented in Chapter 3.2.6.2 and in Chapter 19.1.2.1 in Annex 3. Within the sector, the research projects differentiate between STEAG power stations, other power stations in the hard-coal mining sector, power stations in the lignite mining sector and other boiler combustion for production of steam and hot/warm water.

The majority of emission factors for coking plants have been obtained from BFI (2012). That data source's emission factors for contained sources have been allocated to category 1.A.1.c, since those emissions result primarily from bottom-heating of coke ovens. By contrast, the emission factors determined for fugitive sources have been allocated, by definition, to category 1.B.1.b. In both categories, calculations cover CO emissions from coking plants, along with other pollutants.

3.2.8.3 Uncertainties and time-series consistency (1.A.1.c)

Uncertainties for the activity data were determined for the first time in the 2004 report year (research project FKZ 204 41 132, UBA). The method for determining the uncertainties is described in Annex 2, Chapter 13.6 of the NIR 2007.

The procedure for determining uncertainties for the emission factors is described in Chapter 3.2.6.3.1.

3.2.8.3.1 Result for N_2O

Relatively large numbers of fluidised-bed combustion systems are used in plants within the lignite-mining sector – which plants are part of sector 1.A.1.c. Such systems are known to have relatively higher N_2O emissions than systems using other types of coal-combustion technologies. On the other hand, relevant emissions behaviour in combustion of hard coal and lignite, particularly in fluidised-bed combustion, has been specifically studied, especially in the 1990s. For this reason, enough measurement data were available to permit systematic survey of N_2O emission factors in the research project. The remarks made in Chapter 3.2.6.3.2 apply mutatis mutandis.

3.2.8.3.2 Result for CH_4

The results of Chapter 3.2.6.3.3 apply mutatis mutandis.

3.2.8.3.3 Time-series consistency of emission factors

The results of Chapter 3.2.6.3.4 apply mutatis mutandis.

3.2.8.4 Category-specific quality assurance / control and verification (1.A.1c)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The results of Chapter 3.2.6.4 apply mutatis mutandis.

3.2.8.5 Category-specific recalculations (1.A.1.c)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

3.2.8.6 Planned improvements (category-specific) (1.A.1.c)

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

3.2.9 Manufacturing industries and construction (1. A.2)

This category consists of several sub- categories defined in close harmony with the IPCC categorisations (CRF). It is described in detail via the relevant sub-chapters.

The calculation algorithms for BEU structural elements in category 1.A.2 were revised, within the research project "Substantiation of the data quality of activity data" (FKZ 204 41 132), and they are now governed by a consistent system. For the most part, they are based on reliable data of the Federal Statistical Office.

Sectoral differentiation of activity data was carried out solely for process combustion. A number of reallocations were carried out as a result of the new CRF categorisation.

As of 2008, classification of economic sectors (Wirtschaftszweige = WZ), in energy statistics, is being changed from the "WZ 2003" standard to the "WZ 2008" standard. As a result, activity data relative to process combustion are now being taken from individual statistics in keeping with the relevant key for the change (STATISTISCHES BUNDESAMT 2008: "Umsteigeschlüssel WZ 2003 auf WZ 2008" (key for the change from WZ 2003 to WZ 2008))

As of reporting in 2015, this creates difficulties in allocations to the new CRF categories of the 2006 Guidelines. At the time the 2006 Guidelines were prepared, the 2008 economic sectors (WZ) were not yet known and thus were not taken into account.

With respect to power and heat production, industrial power stations and boiler systems are aggregated by technologies (gas engines, gas turbines, gas and steam plants and steam turbines), as well as by permit-law provisions (TA-Luft and 13th BImSchV).

The various individual calculation algorithms were substantiated in detail in the aforementioned research project.

Following emission calculation at the structural-element level, the sum values for the sub-categories in 1.A.2 were produced pursuant to the 1996 Guidelines – through the 2014 NIR. As of the 2015 NIR, the sum values are produced pursuant to the 2006 Guidelines. In all cases, the aggregation is largely IPCC-conformal. Since the NIR 2006, most process combustion has been reported on a sector-specific basis. The available data do not permit fully IPCC-conformal disaggregation. For example, heat and power production of industrial power stations and thermal power stations cannot be completely oriented to specific sectors; for this reason, it is reported in combined form, under 1.A.2.g. Other.

Differentiation of energy-related process combustion for heat and power production in industrial power stations and in boiler systems was carried out via Statistik 067 (Statistics 067; electricity-production systems of the manufacturing sector, and of the mining and quarrying sectors (Stromerzeugungsanlagen des Verarbeitenden Gewerbes sowie des Bergbaus und der Gewinnung von Steinen und Erden); *STATISTISCHES BUNDESAMT*, 2013c).

A change in Statistics 067 (op. cit.) of the Federal Statistical Office has led to a jump in the activity data for heat and electricity production. Until 2001, only the fuel inputs for electricity production in electricity production systems were listed. As of 2002, fuel inputs for heat and electricity production are listed. No data are available for inputs for heat production for years prior to 2002.

The ratio between the fossil and biogenic fractions in industrial waste is obtained from the Energy Balance, from waste statistics (STATISTISCHES BUNDESAMT, FS 19 Reihe 1) and from the relevant industry association figures for substitute fuels.

All of the listed amounts of standard fuels used in all sub- categories have been taken from the Energy Balance of the Federal Republic of Germany and disaggregated in the Balance of Emission Causes (BEU). In addition to the figures provided from the Energy Balance, in various sub- categories substitute fuels have now been listed. The relevant amounts were determined in a research project (UBA 2005b, FKZ 204 42 203/02) and are now updated annually with the help of association data (see below). This work has shown that substitute fuels are increasingly being used as replacements for more-expensive conventional fuels.

In the research project "Inputs of secondary fuels" ("Einsatz von Sekundärbrennstoffen"; (UBA 2005b, FKZ 204 42 203/02)), the required improvements relative to the topic of "waste fuels" in the energy sector were found to be tied to substitute fuels in four industrial sectors, and the pertinent data were obtained from the relevant industrial associations. As a result, considerably improved, sector-specific data are now available relative to use of substitute fuels in process combustion, and in industrial power stations, in the industrial sectors pig-iron production, pulp and paper production and lime and cement production.

Special aspects of the various sub- categories are described in the relevant sub-chapters. Special note should be taken of the collective group 1.A.2.g Other.

The uncertainties for the new structural elements created in the research project "Substantiation of the data quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten"; (FKZ 204 41 132) were determined in keeping with the method described in the research project 204 42 203/02. That determination is described in the final report for the research project (FKZ 204 41 132) and in Annex 13.6 of the NIR 2007.

Carbon dioxide emissions predominate in CRF category 1.A.2. Other greenhouse gases account for only very small shares of total emissions.

A sharp reduction in greenhouse-gas emissions occurred in the period 1990 through 1994. It was caused by decommissioning of inefficient manufacturing plants in the new German Länder following the 1990 political transition in Germany.

The emissions fluctuations that occurred in subsequent years reflect production trends in Germany's manufacturing sector, which were tied to overall economic trends.

3.2.9.1 Manufacturing industries and construction – iron and steel (1.A.2.a)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T/2	**1.A.2.a Manufacturing Industries and Construction: Iron and Steel**	**All fuels**	**CO_2**	**35,269.3**	**(2.89%)**	**34,080.9**	**(3.65%)**	**-3.4%**
-/-	1.A.2.a Manufacturing Industries and Construction: Iron and Steel	All fuels	N_2O	155.1	(0.01%)	123.1	(0.01%)	-20.6%
-/-	1.A.2.a Manufacturing Industries and Construction: Iron and Steel	All fuels	CH_4	62.5	(0.01%)	73.9	(0.01%)	18.3%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	CS	NS	CS
N_2O	CS	NS	CS
NO_X, CO, NMVOC, SO_2	CS	NS	CS

The category *Manufacturing industries and construction – iron and steel* is a key category for CO_2 emissions, in terms of emissions level and trend and of Tier 2 analysis.

The iron and steel industry (sub- category 1.A.2.a) is the second important CO_2-emissions source, along with the cement industry, in the area of process combustion.

3.2.9.1.1 Source-category description (1.A.2a)

The category comprises the production areas of pig iron (blast furnaces), sinter, rolled steel, iron and steel casting, Siemens-Martin steel, electric steel and the power stations and boilers of the entire steel industry.

Production of Siemens-Martin steel generated emissions only in the new German Länder, and only until shortly after 1990. Thereafter, production was completely discontinued. In the old German Länder, production of Siemens-Martin steel was discontinued before 1990.

In production of pig iron, large amounts of the fuels used in blast furnaces are needed for the reduction processes that take place in the furnaces, while most of the fuel used in other production areas of the iron and steel industry is used for heat production.

The following figure provides an overview of CO_2 emissions in the various sub- categories in 1.A.2.a.

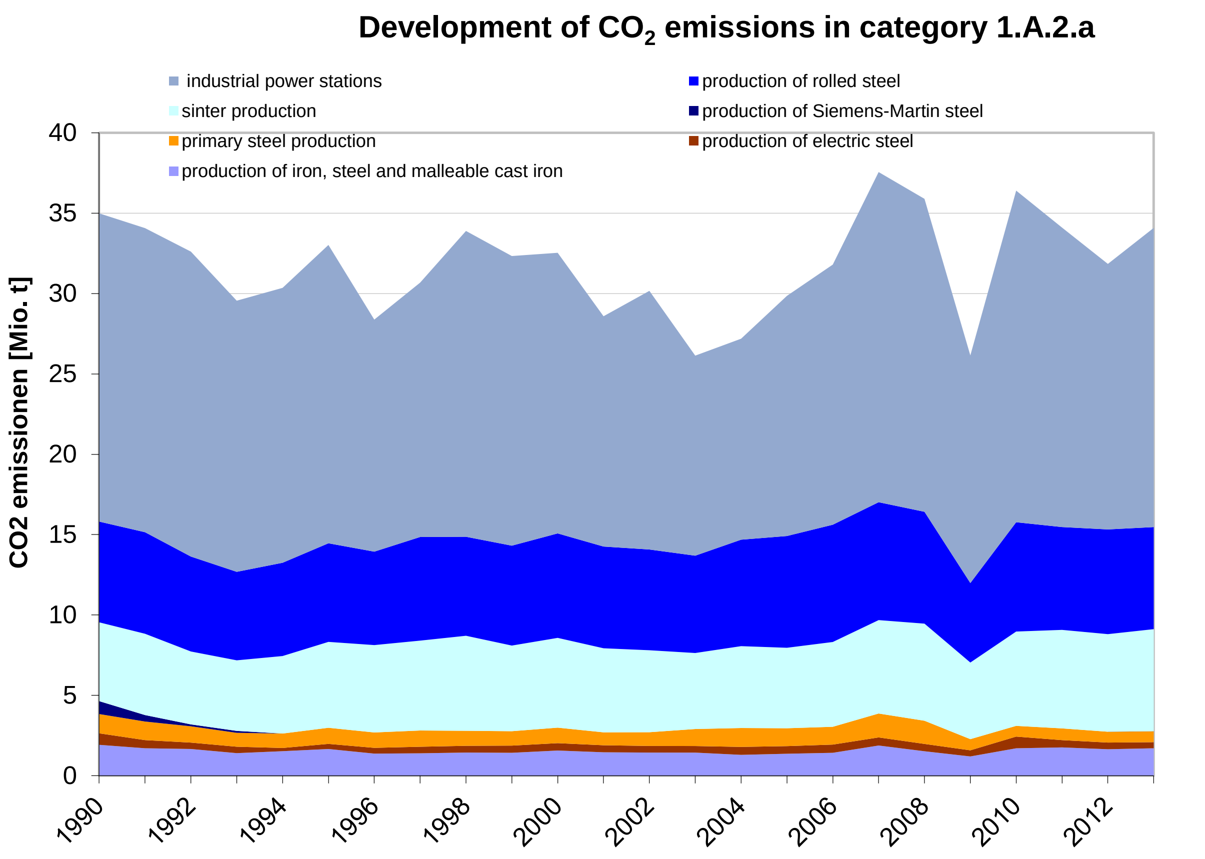

Figure 28: Development of CO_2 emissions in category 1.A.2.a

As the overview reveals, major fluctuations have occurred over the years. In most cases, those swings were tied to fluctuations in production. In the period 1990 through 1994, emissions reductions occurred primarily as a result of restructuring of the iron and steel sector in the new German Länder following the political transition of 1990.

The drop in CO_2 emissions is particularly pronounced in the crisis year 2009, in which the steel industry registered a sharp production decrease. The recurring emissions increase in 2010 resulted from an economic recovery in which the steel industry nearly reattained its production level of 2008. In subsequent years, steel production – and, thus, CO_2 emissions – decreased, but only slightly.

Installations in the areas of rolled-steel and sinter production account for the second-highest shares of emissions, after industrial power stations (which generate electricity for their own use from blast furnace gas and basic oxygen furnace gas). In the blast furnace category, only the natural-gas and coking-gas inputs required for furnace operation are reported in category 1.A.2.a. Process-related emissions are listed in category 2.C.1.

According to the Steel Institute (VDEh), in 2012, as compared with 2011, more coke – but less coke breeze and hard coal – was used in sinter plants. In addition, blast furnace gases, especially basic oxygen furnace gas and coke oven gas, were used as substitutes for natural gas.

In the area of pig-iron production in blast furnaces, inputs of heavy fuel oil have been decreasing continuously since 2010. The heating oil is being replaced largely by PCI coal. This is made possible by conversions of the relevant injection systems. The fuel changes are price-driven. Ultimately, price is the factor that determines whether ground lignite or hard coal is chosen as the fuel.

In 2013, only one iron works used heavy fuel oil in its blast furnace.

3.2.9.1.2 Methodological issues (1.A.2.a)

This sub- category comprises process combustion in the various production areas of the iron and steel industry. The relevant fuel-use amounts, including those for secondary fuels, are contained in the Balance of Emission Causes (BEU).

In work to obtain activity data for conventional fuels in this category, a new data source was developed as of reporting year 2011: the so-called "BGS" group (fuel, gas and electricity industries of blast furnaces, steelworks and rolling mills; and forging plants, press works and hammer mills, including the various other plants (without their own coking plants) locally connected to such operations). That source allows enhanced disaggregation of energy data in the Balance of Emissions Sources (BEU). While the legal basis for surveys relative to the BGS group was no longer available as of reporting year 2012, the pertinent data have since been provided, in the same structure, on the basis of an agreement with the Wirtschaftsvereinigung Stahl German steel industry association. This change has no impact on relevant calculations.

In addition to providing activity data for sintering plants, blast furnaces, basic oxygen furnaces (converters) and rolling mills, BGS-group data support additional disaggregation of the electric steel sector.

The BGS-group data also permit data-based differentiation of the solid-fuel categories "hard coal and hard coal briquettes"; "coke" and "coke breeze with particle size less than 10 mm". In the database, the fuel inputs for coke and coke breeze are listed in sum as "coke", since the energy statistics list the aggregated fuel "coke". The "liquid fuels" listed for the BGS group are classified under "heating oil, heavy".

The BGS-group data list fuel inputs in natural units. For the present purpose, those units are converted into energy units, using the relevant net calorific values listed by the Working Group on Energy Balances (AGEB). For gases, the BGS-group data use a norm of 35.16912 MJ/m^3.

That figure has been adopted in the methods for calculating activity data for blast furnace gas, coke oven gas, natural gas and basic oxygen furnace gas.

The method for calculating emissions from secondary fuels has been retained, in keeping with the results of the research project "Einsatz von Sekundärbrennstoffen" ("Inputs of secondary fuels"; UBA 2005b, FKZ 204 42 203/02).

In the area of emissions from the iron and steel industry, a distinction is made, for the entire time series as of 1990, between process-related emissions and energy-related emissions. The method for calculation of process-related emissions is described in Chapter 4.4.1.2 of category 2.C.1.

3.2.9.1.3 Uncertainties and time-series consistency (1.A.2.a)

Uncertainties were determined for all fuels in 2004 (except for substitute fuels), and for substitute reducing agents, with regard to the entire time series. The relevant method is described in a research report (UBA 2005b, FKZ 204 42 203/02). The uncertainties for the activity data were updated in the research project "Substantiation of the data quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten" (FKZ 204 41 132) and included in the relevant final report.

The statistical data used for calculation until the 2011 report, from the Federal Statistical Office's Fachserie 4 Reihe 8.1, were aggregated in keeping with the BGS-group framework in those statistics. When production of those statistics has been discontinued, the basic BGS-group data will be used directly for calculation.

Direct use of the BGS-group data does not increase the uncertainties. The uncertainties as determined on the basis of the research report were retained, in keeping with the conservative approach applied.

3.2.9.1.4 Category-specific quality assurance / control and verification (1.A.2.a)

General quality control and, for the emission factors and emissions data, category-specific quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

For further information on quality assurance, cf. CRF 1.A.1.a (Chapter 3.2.6.4).

The aforementioned agreement with the steel-industry association calls for the association to carry out quality assurance for the BGS-group data in keeping with the QSE manual.

3.2.9.1.5 Category-specific recalculations (1.A.2.a)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

3.2.9.1.6 Planned improvements (category-specific) (1.A.2.a)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

3.2.9.2 Manufacturing industries and construction – non-ferrous metals (1.A.2b)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/-	1.A.2.b Manufacturing Industries and Construction: Non-Ferrous Metals	All fuels	CO_2	1,629.2	(0.13%)	1,564.6	(0.17%)	-4.0%
-/-	1.A.2.b Manufacturing Industries and Construction: Non-Ferrous Metals	All fuels	N_2O	17.1	(0.00%)	8.1	(0.00%)	-53.0%
-/-	1.A.2.b Manufacturing Industries and Construction: Non-Ferrous Metals	All fuels	CH_4	1.4	(0.00%)	1.7	(0.00%)	25.3%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	CS	NS	CS
N_2O	CS	NS	CS
NO_X, CO, NMVOC, SO_2	CS	NS	CS

The category *Non-ferrous metals* is not a key category.

3.2.9.2.1 Category description (1.A.2.b)

This category aggregates process combustion of various areas of non-ferrous-metal production. The available data do not support more detailed description.

3.2.9.2.2 Methodological issues (1.A.2.b)

The pertinent fuel inputs are contained in the Balance of Emission Causes (BEU). The source for fuel inputs consists of statistics for the manufacturing sector (Statistik 060 – Energieverwendung des produzierenden Gewerbes (energy use in the manufacturing sector; *STATISTISCHES BUNDESAMT* (Federal Statistical Office) 2011b) (Melde-Nr. (reporting number) 27.43 (WZ 2003 old; WZ = classification system for economic data) → 24.43 (WZ 2008 new); Erzeugung und erste Bearbeitung von Blei, Zink und Zinn (production and initial processing of lead, zinc and tin) 27.44 (WZ 2003 old) → 24.44 (WZ 2008 new); Erzeugung und erste Bearbeitung von Kupfer (production and initial processing of copper)) and, for differentiations relative to heat and electricity production, Statistik 067 (*STATISTISCHES BUNDESAMT*, 2013c).

Descriptions of calculation algorithms for activity data in the Balance of Emissions Sources (BEU) were revised in the interest of standardisation, consistency and transparency.

As a result of such revision, production and initial processing of precious metals, aluminium and other non-ferrous metals are now taken into account in determination of activity data.

The relevant calculation algorithms are described in detail in the final report for the research project "Substantiation of the data quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten") (FKZ 204 41 132).

The 1990 activity data for the new German Länder were revised and substantiated, with the help of new data, in the project "Base year and updating" ("Basisjahr und Aktualisierung" (UBA 2005c: FKZ 205 41 115); see Annex Chapter 19.1.1).

3.2.9.2.3 Uncertainties and time-series consistency (1.A.2.b)

Uncertainties for all activity data were determined in 2004. The relevant method is described in Annex Chapter 13.6 of the NIR 2007.

3.2.9.2.4 Category-specific quality assurance / control and verification (1.A.2.b)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

For further information on quality assurance, cf. CRF 1.A.1.a (Chapter 3.2.6.4).

3.2.9.2.5 Category-specific recalculations (1.A.2.b)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

3.2.9.2.6 Planned improvements (category-specific) (1.A.2.b)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

3.2.9.3 Manufacturing industries and construction – Chemicals (1.A.2.c)

CRF 1.A.2.c	Gas	Key category		1990 Total emissions (Gg) & percentage (%)		2012 Total emissions (Gg) & percentage (%)		Trend
All fuels	IE	IE	IE	IE	IE	IE	IE	IE

In the chemical industry, the main relevant plants consist of industrial power stations and boilers. Such installations are reported, for all sectors, in sub- category 1.A.2.g Other.

Fuel inputs in calcium-carbide production are process-related and are reported under CRF 2.B.5 (cf. Chapter 4.3.5).

This approach has been confirmed by the research project "Base year and updating" (UBA 2005c, FKZ 205 41 115), for 1990 in the new German Länder (the most important production location): the relevant coke was used as a production material and not as a fuel for energy. Calcium-carbide production is thus not a source of energy-related CO_2 emissions.

The emissions for the entire sub- category 1.A.2.c are thus included elsewhere (IE). For this reason, sub- category 1.A.2.c is not listed separately in the key-category analysis.

The majority of the emissions in the chemical industry originate in combustion processes. Since fuel-input data for the chemical industry are available only as of the year 2003, no time series as of 1990 can be produced. For this reason, emissions from energy-related use of fuels in the chemical industry are reported together with emissions for other industrial sectors in category 1.A.2.g "Other". Nonetheless, the available data can be cross-checked against relevant available data from emissions trading. As this is done, double counting with the IPPU Sector has to be avoided. In addition, it is important to ensure that emissions from combustion of other produced gases are not underestimated. The comparison shows that the data reported in energy statistics for the year 2012 agree best with the fuel-quantity data from emissions trading. No statistics are yet available for the year 2013. The gas quantities given by statistics for earlier years are too low overall. The first analytical step, therefore, was to identify the chemical industry areas in which other produced gases occur and are used for energy generation. Overall half of the total gas produced is used in production of other organic basic materials and chemicals. The next-largest share is used in production of other inorganic basic materials and in production of dyes and pigments. A still-smaller share of these gases is used in production of plastics in primary forms. For recalculation of the relevant gas consumption, the main products produced in each sector were determined. The pertinent data are available, for the period back to 1990, in the annual "Chemiewirtschaft in Zahlen" ("Chemical industry figures") reports of the VCI. Data are lacking only for the new German Länder in the year 1990. Since the Energy Balance lists major quantities of "fuel gases" ("Brenngase") for the new German Länder, it may be assumed that those gases have been taken into account at least in the area of energy use. With the help of the production data, and the gas-quantity data listed in the energy statistics for the year 2013, specific factors were developed, for each sub-sector, with which it was possible to calculate the pertinent fuel inputs retroactively.

3.2.9.4 Manufacturing industries and construction – Pulp, paper and print (1.A.2.d)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/-	1.A.2.d Manufacturing Industries and Construction: Pulp, Paper and Print	All fuels	CO_2	3.6	(0.00%)	7.8	(0.00%)	113.8%
-/-	1.A.2.d Manufacturing Industries and Construction: Pulp, Paper and Print	All fuels	N_2O	2.8	(0.00%)	11.7	(0.00%)	317.7%
-/-	1.A.2.d Manufacturing Industries and Construction: Pulp, Paper and Print	All fuels	CH_4	0.7	(0.00%)	2.7	(0.00%)	317.7%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	CS	NS	CS
N_2O	CS	NS	CS
NO_X, CO, NMVOC, SO_2		IE	

The category *Pulp, paper and print* is not a key category.

3.2.9.4.1 Category description (1.A.2.d)

The energy consumption for production of pulp, paper and printed products – otherwise referred to as the "pulp and paper industry" for short – can be described only for substitute fuels, of which this industry uses large amounts.

Emissions from use of regular fuels in process combustion, and emissions generated by plants in own-power production, have not been listed separately. They are summarised under 1.A.2.g Other.

3.2.9.4.2 Methodological issues (1.A.2.d)

Only some of the substitute fuels used by the paper industry are listed in the Energy Balance. The fuels in question consist of waste from the relevant sectors' own production areas. The data on the types and amounts of substances used were provided by the German Pulp and Paper Association (VDP). The great majority of the substitute fuels used in the sector consist of wood and pulp fibres – and, thus, of biomass. The biogenic and fossil fractions of pertinent fuels were derived in the research project "Inputs of secondary fuels" ("Einsatz von

Sekundärbrennstoffen") (UBA 2005b, FKZ 204 42 203/02). In addition, CO_2 emission factors were derived on the basis of data on carbon content, water content and net calorific values.

The official statistical data on inputs of standard fuels in the paper industry were reviewed.

In the statistics for the manufacturing sector (Statistik 060 – Energieverwendung des produzierenden Gewerbes ("energy use in the manufacturing sector"); *STATISTISCHES BUNDESAMT* 2013b), under the new system for classification of economic activities (Wirtschaftszweigsystematik – WZ 2008 new), the source for the fuel inputs is assigned WZ number 17 "Herstellung von Papier, Pappe und Waren daraus" (production of paper, cardboard and related goods").

At present, the source for one time series cannot be unambiguously assigned in keeping with the old system for classification of economic activities (WZ 2003).

The class WZ 17 within the new system for classification of economic activities (Wirtschaftszweigsystematik 2008) corresponds to classes WZ 17, 21, 22 and 36 under the old system, WZ 2003.

Currently, the individual fuel inputs cannot be listed in disaggregated form, due to the need to protect confidentiality.

The same applies for Statistik 067 (*STATISTISCHES BUNDESAMT*, 2013c), which is used for differentiation from electricity and heat generation.

3.2.9.4.3 Uncertainties and time-series consistency (1.A.2.d)

In the framework of a research project, the uncertainties of the CO_2 emission factors derived for substitute fuels were determined using the Monte Carlo method (UBA 2005b, FKZ 204 42 203/02). In the procedure, figures for C content, water content and net calorific value were taken into account. Such figures are based on varying estimates, as well as on small numbers of measurements and analysis results, and thus show wide spreads. The CO_2 emission factors for secondary fuels, along with the relevant uncertainties, apply throughout the entire relevant time series, because no findings on trends are available. The time series are thus consistent.

3.2.9.4.4 Category-specific quality assurance / control and verification (1.A.2.d)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The paper industry has long kept records of inputs of secondary fuels (VDP, various years). In spite of small structural breaks in the time series in such records, the records clearly show the paper industry's increasing use of substitute fuels in place of regular fuels.

3.2.9.4.5 Category-specific recalculations (1.A.2.d)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

3.2.9.4.6 *Planned improvements (category-specific) (1.A.2.d)*

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

3.2.9.5 Manufacturing industries and construction – Sugar production (1.A.2.e)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/T	**1.A.2.e Manufacturing Industries and Construction: Food Processing**	**All fuels**	**CO_2**	**2,015.9**	**(0.17%)**	**303.8**	**(0.03%)**	**-84.9%**
-/-	1.A.2.e Manufacturing Industries and Construction: Food Processing	All fuels	N_2O	24.6	(0.00%)	3.2	(0.00%)	-87.1%
-/-	1.A.2.e Manufacturing Industries and Construction: Food Processing	All fuels	CH_4	4.5	(0.00%)	0.3	(0.00%)	-94.2%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	CS	NS	CS
N_2O	CS	NS	CS
NO_X, CO, NMVOC, SO_2	CS	NS	CS

The *Sugar production* category is a key category for CO_2 emissions in terms of trend (cf. Table 6). Because relevant emissions have fallen sharply since 1990 (-90.41 %), and thus an extremely low emissions level has been attained, the Single National Entity has decided, as part of its resources prioritisation, not to apply the more stringent methods to this category that are required for key categories.

3.2.9.5.1 *Source-category description (1.A.2.e)*

This category includes only the sugar industry's process combustion. Plants generating their own power are not listed separately; they are reported under 1.A.2.g Other.

3.2.9.5.2 *Methodological issues (1.A.2.e)*

Descriptions of calculation algorithms for activity data in the Balance of Emissions Sources (BEU) were revised in the interest of standardisation, consistency and transparency.

As a result of this revision, it was determined that the statistics publications Statistik 060 (*STATISTISCHES BUNDESAMT*, 2013b) and Statistik 067 (*STATISTISCHES BUNDESAMT*, 2013c) list all of the fuels required for calculation of the pertinent activity data and should be used as data sources.

The relevant calculation algorithms, and special analyses relative to fuel inputs, are described in detail in the final report for the research project "Substantiation of the data quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten") (FKZ 204 41 132).

3.2.9.5.3 *Uncertainties and time-series consistency (1.A.2.e)*

For 2004, the uncertainties for all activity data were determined for the first time. The relevant method is described in Annex Chapter 13.6 of the NIR 2007.

3.2.9.5.4 *Category-specific quality assurance / control and verification (1.A.2.e)*

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

For further information on quality assurance, cf. CRF 1.A.1.a (Chapter 3.2.6.4).

3.2.9.5.5 *Category-specific recalculations (1.A.2.e)*

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

3.2.9.5.6 *Planned improvements (category-specific) (1.A.2.e)*

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

3.2.9.6 Manufacturing industries and construction – Non-metallic minerals industry (1.A.2.f)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T	**1.A.2.f Manufacturing Industries and Construction: Non-metallic minerals**	**All fuels**	**CO_2**	**18,507.4**	**(1.52%)**	**13,072.8**	**(1.40%)**	**-29.4%**
-/-	1.A.2.f Manufacturing Industries and Construction: Non-metallic minerals	All fuels	N_2O	205.3	(0.02%)	121.7	(0.01%)	-40.7%
-/-	1.A.2.f Manufacturing Industries and Construction: Non-metallic minerals	All fuels	CH_4	50.3	(0.00%)	15.1	(0.00%)	-70.0%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	CS	NS	CS
N_2O	CS	NS	CS
NO_X, CO, NMVOC, SO_2	CS/IE	NS/IE	CS/IE

The category *Manufacturing industries and construction – Non-metallic minerals industry*, the sum of all other sub- categories, is a key category, in terms of emissions level and trend, for CO_2 emissions.

In general in the inventory, those categories are listed separately in which combustion systems with a specific emissions behaviour – so-called "process combustion" systems – are used. For this reason, the sub- categories 1.A.2.f Cement (structural element "Production of cement clinkers (process combustion)"), 1.A.2.f Ceramics (structural element "Production of ceramics products (process combustion)"), 1.A.2.f Glass (structural element "Production of glass (process combustion)") and 1.A.2.f Lime (structural element "Production of lime (process combustion)") are listed individually.

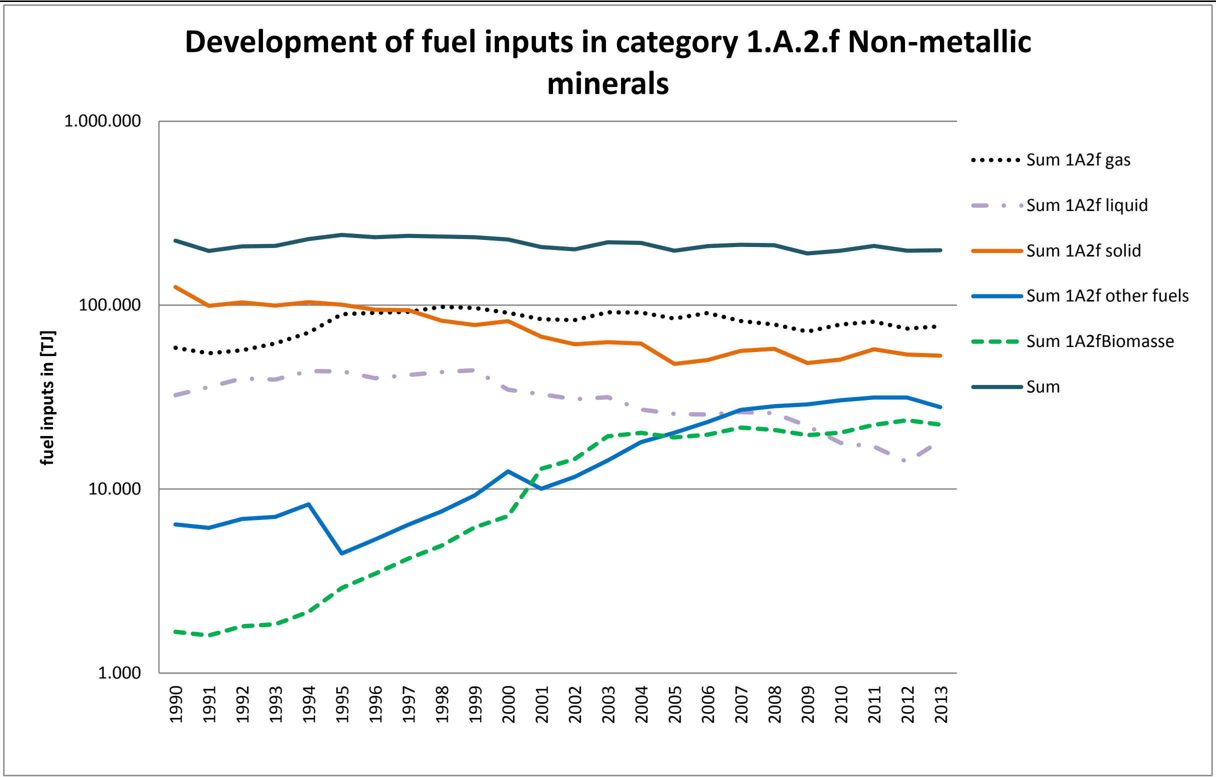

Figure 29: Development of fuel inputs in category 1.A.2.f Non-metallic minerals

Two changes of fuels occurred in the area of the non-metallic minerals industry.

In the mid-1990s, solid fuels were supplanted by gaseous fuels. These two fuel groups are predominant in this category.

In the mid-2000s, liquid fuels were supplanted by waste and secondary fuels. Additional fuel substitutions then occurred a few years later, as biomass fuels were introduced.

3.2.9.6.1 Source-category description (1.A.2.f, Non-metallic minerals industry)

In this category, process combustion from burning of clinkers is listed. The final step in cement production, i.e. grinding and mixing, is not included. As a power-intensive process, it is included in power production (1.A.1). In addition, process combustion in the brick industry, and in production of other structural ceramics, are reported as well. In the glass industry, process combustion includes production of flat glass, hollow glass and glass fibres; shaping and processing of flat glass; and production and shaping of other types of glass and technical glassware. Process combustion in lime production is also taken into account. Some plants within this category also generate power for their own use; such generation is not listed separately, but is included under 1.A.2.g "Other".

3.2.9.6.2 Methodological issues (1.A.2.f, Non-metallic minerals industry)

The pertinent inputs of conventional fuels are contained in the Balance of Emission Sources (BEU). The fuel-input data for energy-related process combustion are obtained from the manufacturing sector's own statistics. The following numbers from the WZ classification of industrial sectors are relevant: Reporting number (Melde-Nr.) 26.51(WZ 2003 old) → 23.51 (WZ 2008 new), Cement production; Reporting number 26.40 (WZ 2003 old) → 23.32 (WZ 2008 new), Brick production, Production of other structural ceramics; Reporting number 26.1

(WZ 2003 old) → 23.1 (WZ 2008 new), Production of glass and glassware; and Reporting number 26.52 (WZ 2003 old) → 23.52 (WZ 2008 new), Lime production. As a result of the change in the reporting numbers, the data for lime can no longer be easily separated from those for gypsum. The necessary differentiation is achieved with the help of a split factor determined on the basis of individual statistics. For differentiation from heat and electricity production, cf. Statistik 067 (*STATISTISCHES BUNDESAMT* (Federal Statistical Office), 2013c).

As of 2002, the data for Statistik 067 (op. cit.) are found only among three-digit reporting numbers. This means that only data for reporting number 26.5 (WZ 2003 old) → 23.5 (WZ 2008 new) (production of cement, lime and burnt plaster) can be used as a basis.

The relevant calculation algorithms are described in detail in the final report for the research project "Substantiation of the data quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten") (FKZ 204 41 132) and in the 2013 NIR, 3.2.9.7 through 3.2.9.10.

The fuel inputs for the new German Länder in 1990 were calculated on the basis of specific fuel consumption in 1989 and production in 1990.

The cement industry and lime industry use significant amounts of substitute fuels that do not appear in national statistics and in the Energy Balance. Relevant production figures and fuel-use quantities are taken from statistics of the relevant industry associations. The procedure used to compile activity data oriented to the old and new German Länder as of 1990, and to all of Germany as of 1995, is described in the final report of the research project "Inputs of secondary fuels" ("Einsatz von Sekundärbrennstoffen"; UBA 2005b, FKZ 204 42 203/02). In a first step, fuel inputs were allocated to the groups "Biomass" or "Other fuels (waste)", in keeping with IPCC procedures. In the research project "Inputs of secondary fuels", the biogenic fractions of relevant fuels were derived and then entered into the calculations, with the help of split factors. In the same project, CO_2 emission factors were derived for substitute fuels, on the basis of data on carbon content, water content and net calorific value (UBA 2005b, FKZ 204 42 203/02).

3.2.9.6.3 *Uncertainties and time-series consistency (1.A.2.f, Non-metallic minerals industry)*

Uncertainties were determined for all fuels in 2004 and for the aforementioned substitute fuels with regard to the entire time series. The relevant methods are explained in Annex Chapter 13.6 of the NIR 2007 and in the final report of the research project (UBA 2005b, FKZ 204 42 203/02).

The uncertainties for the activity data were updated in the research project "Substantiation of the data quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten" (FKZ 204 41 132) and included in the relevant final report.

The activity data for the new German Länder, for base year 1990 and the following years, 1991-1994, were adjusted in keeping with findings from the pertinent research project (FKZ 205 41 115 / Sub-project A "Revison and substantiation of fuel inputs for stationary combustion plants in the new German Länder for the year 1990"). The relevant recalculation method is described in the Annex, Chapter 19.1.2.1.

3.2.9.6.4 Category-specific quality assurance / control and verification (1.A.2.f, Non-metallic minerals industry)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

For further information on quality assurance, cf. CRF 1.A.1.a (Chapter 3.2.6.4).

3.2.9.6.5 Category-specific recalculations (1.A.2.f, Non-metallic minerals industry)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

3.2.9.6.6 Planned improvements (category-specific) (1.A.2.f, Non-metallic minerals industry)

No further improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

3.2.9.7 Manufacturing industries and construction – Other energy production (1.A.2.g, Other, stationary + mobile)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T/2	**1.A.2.g Manufacturing Industries and Construction: Other (stationary + mobile)**	**All fuels**	**CO_2**	**127,691.6**	**(10.48%)**	**76,160.0**	**(8.15%)**	**-40.4%**
-/-	1.A.2.g Manufacturing Industries and Construction: Other (stationary + mobile)	All fuels	N_2O	937.6	(0.08%)	525.8	(0.06%)	-43.9%
-/-	1.A.2.g Manufacturing Industries and Construction: Other (stationary + mobile)	All fuels	CH_4	130.7	(0.01%)	171.7	(0.02%)	31.3%

The stationary and mobile sources categories in 1.A.2.g are placed in the relevant main categories together. Accordingly, the category *1.A.2.g Manufacturing – Other energy generation* is a key category for CO_2 in terms of emissions level and trend and of Tier 2 analysis.

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	CS	NS	CS
N_2O	CS	NS	CS
NO_X, CO, NMVOC, SO_2	CS	NS	CS

As a result of its function as a collective category for fuel inputs that cannot be disaggregated to the individual-sector level, this sub- category is particularly significant; it contributes substantially to the entire energy sector's CO_2 emissions.

3.2.9.7.1 Source-category description (1.A.2.g Other, stationary)

In this sub- category, all those emissions are reported for which the relevant energy inputs cannot be disaggregated in keeping with the categories in 1.A.2. This sub- category is responsible for about 70 % of all CO_2 emissions of category 1.A.2.

All electricity and heat generation in industrial power stations and boilers is listed in this sub-category, because such systems can justifiably be grouped together, in light of their emissions behaviour. Since the chemical industry primarily uses CHP systems and boilers, the pertinent emissions from category 1.A.2.c are reported in sub- category 1.A.2.g "Other". Any further subdivision of industrial power stations and boilers, among the otherwise planned sub-categories, would not improve the data, since such systems' emissions behaviour does not depend on the industrial sector involved. Time series are difficult to prepare, since in 1990 Germany consisted of two countries. Those two countries had two different statistical systems, and those systems were combined during a transition period lasting until 1994. Great efforts were made to provide the required documentation and quality data for the reference year, 1990. In addition, in 2003 the Act on Energy Statistics (Energiestatistikgesetz) was amended. This considerably improved data collection, especially for CHP systems. Such data for the period cannot be retroactively collected for the period 2002 – 1990, however. By and large, time-series consistency has been achieved at the aggregated level. Any further disaggregation would lead to breaks in the time series, however, because the data are not all available in disaggregated form, and cannot all be systematically allocated. Nonetheless, the possibilities for further disaggregation have been carefully reviewed. No successful solution for this problem has been found, however. Also, many energy data in Germany are subject to confidentiality restrictions, and thus often must be aggregated (aggregation safeguards confidentiality). In many sectors that have been listed separately to date, data for certain fuels now have to be combined, for reasons of confidentiality, and reported in category 1.A.2.g "Other". This considerably reduces the conclusiveness of the data in various individual sectors.

Ultimately, the boundary between the various individual industrial sectors and the public supply sector cannot be unambiguously drawn. The "autoproducers" described in the IPCC Guidelines hardly exist in reality in the clear-cut form outlined. Different companies manage their electricity and heat generation in different ways. Some companies operate power stations of their own that often also feed electricity into the public grid. Other companies draw electricity and/or heat from the public grid. As a result of energy-market liberalisation, the structures in this area often change. Since national statistics serve as the basis for inventory preparation, the inventory adopts those statistics' sectoral allocations of the various kinds of installations and plants involved. Such allocations do not remain constant throughout the time series, and they are not thoroughly consistent with the corresponding allocations in the emissions trading sector. As a result, they cannot be harmonized in the existing data records.

International comparisons of those sub- categories in which industrial power stations play the primary role are not feasible, since the pertinent supply structures differ considerably from country to country.

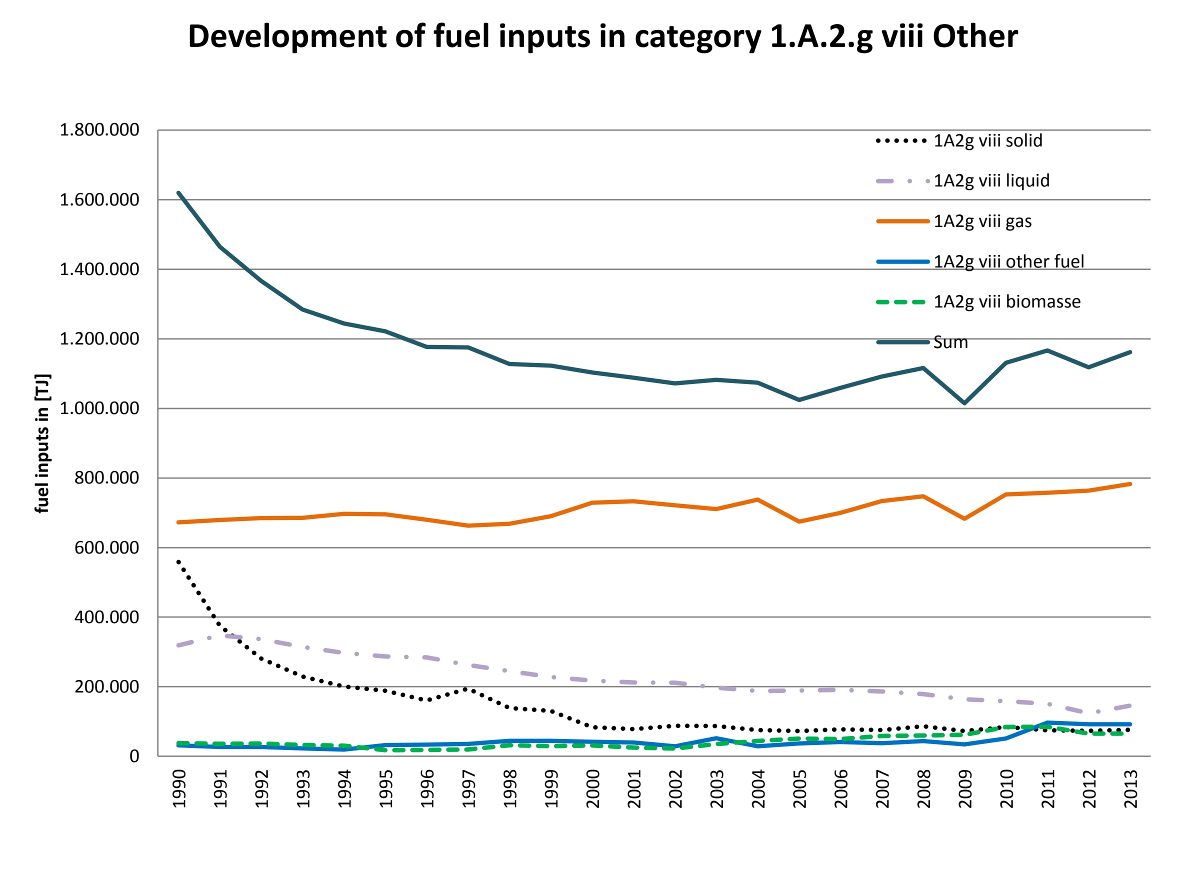

Figure 30: Development of fuel inputs in category 1.A.2.g viii Other

This category exhibits a marked change in fuel inputs.

A decrease in the use of solid fuels – including, especially, a significant reduction in the use of lignite – is especially noticeable. On the other hand, use of gas, biomass and substitute fuels (waste) increased.

A statistical discontinuity is seen in the area of biomass. Prior to the entry into force of the Act on Energy Statistics (Energiestatistikgesetz), biomass inputs for energy generation either were not recorded statistically or were recorded only in part. The biomass fraction has been growing continuously.

In 2012, in comparison to the previous year, the quantities listed in waste statistics relative to inputs of industrial waste in combustion systems, and to hazardous waste (STATISTISCHES BUNDESAMT, FS 19 Reihe 1), remained virtually constant, while the figures for "other gases" in the Energy Balance decreased significantly. This led to a considerable decrease in the "other fuels" category in 2012. In 2013, increased consumption of gas and heating oil produced another slight increase overall in this category.

3.2.9.7.2 Methodological issues (1.A.2.g Other, stationary)

The fuel inputs for electricity generation in industrial power stations are shown in Energy Balance line 12. The difference resulting after deduction of the fuel inputs for refinery power stations, mine power stations, power stations in the hard-coal-mining sector and, for the period until 1999, for the power stations of Deutsche Bahn (German Railways) consists of the activity data for other industrial power stations. These data cannot be further differentiated at present.

Additional data from the Federal Statistical Office are needed for allocation of fuel inputs to heat production in industrial power stations and boiler systems. Fuel inputs for heat production in CHP systems can be determined from relevant statistics. The activity data for boiler systems are calculated as the pertinent difference.

For both electricity generation and heat generation, the data are broken down into the categories steam turbines, gas turbines, gas-and-steam (combined cycle) systems and gas engines, since (for the present purpose) these different combustion technologies differ especially in terms of their methane emissions. This breakdown, which has been revised for the current report, is described under 1.A.1.a.

A detailed description of the relevant calculation algorithms, which were extensively revised for the 2008 reporting year, is provided in the final report for the research project "Substantiation of the data quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten"; FKZ 204 41 132).

With the new data source "BGS-Bogen" ("BGS form; see above), it has become possible to list, separately, use of blast furnace gas for energy production in live-steam boilers in the iron and steel industry.

In some years, the total energy quantity listed in Energy Balance line 54 (metal production), for use of blast furnace gas, is lower than the total blast-furnace-gas input as shown by the BGS data. In such cases, the Energy Balance data are supplemented with the BGS-form data.

Emission factors

A list of the CO_2 emission factors used, and a description of the relevant methods, are provided in the Annex, Chapter 18.7.

All other emission factors for greenhouse gases and precursor substances, for power stations and other boiler combustion for production of steam and hot/warm water, in category 1.A.1.f / all other, have been taken from RENTZ et al (2002) and FICHTNER et al (2011). A detailed description of the procedure is presented in Chapter 3.2.6.2 and in Chapter 19.1.2.1 in Annex 3. The research projects break down the relevant sector into power stations of Deutsche Bahn AG, other industrial power stations and other boiler combustion systems for production of steam and hot/warm water.

3.2.9.7.3 Uncertainties and time-series consistency (1.A.2.g, Other, stationary)

Activity data

The uncertainties were determined, for the first time, for 2004. The relevant method is described in Annex Chapter 13.6 of the NIR 2007.

The uncertainties for the activity data were updated in the research project "Substantiation of the data quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten" (FKZ 204 41 132) and included in the relevant final report.

Emission factors

The procedure for determining uncertainties is described in Chapter 3.2.6.3.1.

Result for N_2O: The results of Chapter 3.2.6.3.2 apply mutatis mutandis.

Result for CH_4: The results of Chapter 3.2.6.3.3 apply mutatis mutandis.

The results obtained in Chapter 3.2.6.3.4 in determination of time-series consistency apply mutatis mutandis.

3.2.9.7.4 Category-specific quality assurance / control and verification (1.A.2.g, Other, stationary)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

For further information on quality assurance, cf. CRF 1.A.1.a (Chapter 3.2.6.4).

Activity data

The quality of the data was reviewed in the research project "Substantiation of the data quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten"; FKZ 204 41 132) and improved via use of statistics of the Federal Statistical Office as a database. No other data sources with long-term availability have been identified.

Emission factors

The results obtained in Chapter 3.2.6.4, in the general procedure for category-specific quality assurance / control and verification, apply mutatis mutandis.

3.2.9.7.5 Category-specific recalculations (1.A.2.g, Other, stationary)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

3.2.9.7.6 Planned improvements (category-specific) (1.A.2.g, Other, stationary)

Activity data:

No improvements are planned at present.

Emission factors:

No further improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

3.2.9.8 Construction-sector transports (1.A.2.g vii)

3.2.9.8.1 Source-category description (1.A.2.g vii)

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1*, CS	NS/M	CS, D*
CH_4	CS (Tier 2)	NS/M	CS (M)
N_2O	CS (Tier 2)	NS/M	CS (M)

* biodiesel and co-combusted lubricants

The stationary and mobile sources categories in 1.A.2.g are placed in the relevant main categories together (for an overview, cf. Chapter 3.2.9.7.). Accordingly, the category *1.A.2.g vii*

– *Other: Offroad vehicles and other machinery,* in which emissions from construction-sector transports are taken into account, is a key category for CO_2 in terms of emissions level and trend.

3.2.9.8.2 Methodological issues (1.A.2.g vii)

Pursuant to (IPCC 2006 Guidelines; page 3.33; equation 3.3.2), the emissions are calculated, using a Tier 2 method, as products of consumed fuels and technology-specific emission factors.

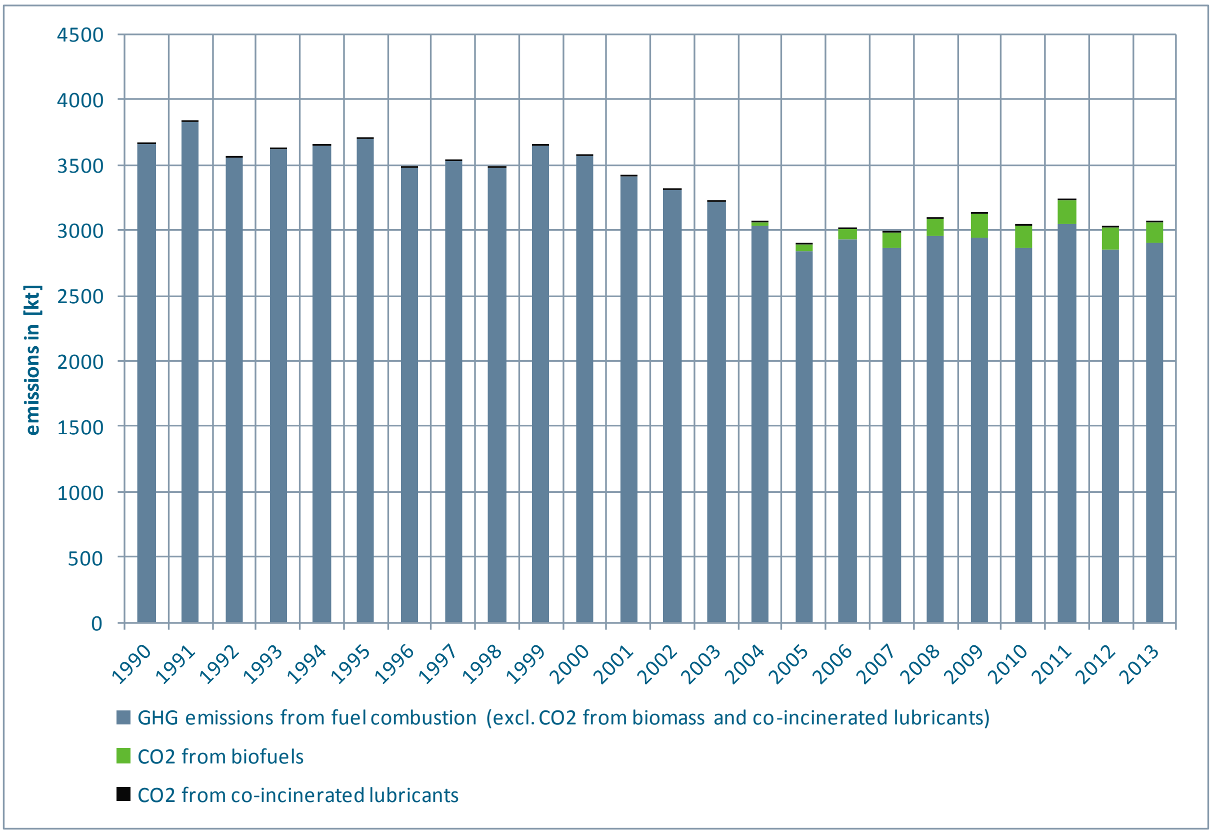

Figure 31: Development of GHG emissions from vehicles and mobile construction-sector machinery, 1990-2013

The **activity data** for diesel oil and gasoline, including their biogenic admixtures, are calculated, following deduction of energy inputs for military transports, from the data in NEB lines 79 (until 1994) and 67 *"Commerce, trade, services and other consumers"*). Finer allocation of fuel quantities to mobile sources in the construction sector (1.A.2.g vii), commerce & trade (1.A.4.a ii), agriculture (1.A.4.c ii (1) and forestry (1.A.4.c ii (ii)) is achieved with the help of annually fluctuating split factors modelled in TREMOD-MM (IFEU 2014b).

The pertinent quantities of co-combusted lubricants are derived, pursuant to (VSI, 2014), from the relevant annual fuel quantities.

The relevant **emission factors** are based on the results of various Federal Environment Agency research projects and expert opinions.

With regard to the CO_2 emission factors used, we refer to Chapter 18.7.

For methane and nitrous oxide, country-specific values are used that are taken from (IFEU, 2014b). The development of these values reflects the gradual phasing-in of emissions standards, since the mid-1990s, for construction-sector machinery.

Table 24: EF(CH_4) und EF(N_2O) 2013, in [kg/TJ]; in parentheses: Default values pursuant to (IPCC, 2006)[1)]

	CH_4	N_2O	Origin
Diesel oil	1.31 (4.15)	2.92 (28.60[27])	country-specific values pursuant to (IFEU, 2014b)
Biodiesel	1.31 (-)	2.92 (-)	equivalent to the EF for diesel oil
Gasoline	19.76 (50)	1.41 (2.00)	pursuant to (EMEP/EEA, 2013) and (IFEU, 2014b)
Bioethanol	19.76 (-)	1.41 (-)	equivalent to the EF for gasoline
Lubricants	IE	IE	included in the EF for fuels

[1)] The values given are defaults for "Industry" pursuant to Table 3.3.1 of the IPCC 2006 Guidelines

With regard to releases of these two greenhouse gases from co-combustion of lubricants, it is assumed that such emissions are already taken into account in the pertinent emission factors for the fuels used and thus are to be reported as IE *(included elsewhere)*.

3.2.9.8.3 Uncertainties and time-series consistency (1.A.2.g vii)

The uncertainties figures for the activity data and EF(CO_2) are based on experts' assessments. While the EF(CH_4) are based on results from (IFEU & INFRAS, 2009), the EF(N_2O) – for the time being – has to be oriented to guideline values pursuant to the IPCC.

Furthermore, the methodological discontinuity in the time series for the EF(N_2O) has been eliminated. This has established time-series consistency for the first time.

3.2.9.8.4 Category-specific quality assurance / control and verification (1.A.2.g vii)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

Quality reports of the Working Group on Energy Balances (AG Energiebilanzen – AGEB) have been submitted to the Federal Environment Agency, for purposes of quality assurance of the Energy Balances.

Table 25: Overview of relevant comparisons

Comparison with...	Completed	Remark
alternative emissions inventories for Germany	no	no comparable data records
category-specific Tier 1 default EF pursuant to (IPCC, 2006; Table 3.3.1: Industry): CO_2	yes	cf. Table 26
category-specific Tier 1 default EF pursuant to (IPCC, 2006; Table 3.3.1: Industry): CH_4, N_2O	yes	cf. Table 24
specific IEF of other countries	yes	cf. Table 27

[27] This default value is now seen as outdated, because the cited original source (EMEP/CORINAIR: Emission Inventory Guidebook – 2005) has since been revised.

Table 26: Comparison of the EF(CO_2) used in the inventory with default values

	Inventory value	Default	*Lower bound*	*Upper bound*
Diesel oil	74,000	74,100	*72,600*	*74,800*
Gasoline	73,091[1)]	69,300	*67,500*	*73,000*
Co-combusted lubricants[2)]	73,300	73,300	*71,900*	*75,200*
Biodiesel	70,800	70,800	*59,800*	*84,300*
Bioethanol	71,607	70,800	*59,800*	*84,300*

[1)] value for 2013

[2)] CO_2 from co-combustion of lubricants (except for two-stroke engines!) is reported under CRF 2.D.1

The following table provides a comparison with specific implied emission factors of other countries as well as with the relevant values resulting for the EU(28). It should be noted that the comparison is hampered by the fact that the factors involved represent a heterogeneous group of categories.

Table 27: International comparison of reported IEF (all figures in [kg/TJ])

	Fossil liquid fuels			Definition pursuant to CRF Table1.A(a)s2
	CO_2	CH_4	N_2O	
Germany	73,979	1.73	2.89	Construction machinery
Denmark	73,228	2.57	3.11	Non-road machinery
France	*81,018*	*4.23*	*1.94*	*Other non-specified: Liquid fuels*
Netherlands	74,300	5.00	0.60	Machinery
Norway	*70,222*	*4.13*	*0.66*	*Other non-specified: Liquid fuels*
Switzerland	*74,131*	*1.63*	*1.33*	*Glass, cement, mineral wool*
UK	*70,694*	*5.46*	*11.43*	*Other non-specified: Liquid fuels*
EU (28)	*78,787*	*4.16*	*6.54*	*Other non-specified: Liquid fuels*

Germany: current IEF for 2013; all other countries: IEF for 2012, pursuant to 2014 CRF Tables

3.2.9.8.5 Category-specific recalculations (1.A.2.g vii)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

3.2.9.8.6 Planned improvements (category-specific) (1.A.2.g vii)

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

3.2.10 Transport (1.A.3)

3.2.10.1 Transport – Domestic aviation (1.A.3.a)

3.2.10.1.1 Category description (1.A.3.a)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/-	1.A.3.a Transport: Domestic Aviation	All fuels	CO_2	2,463.1	(0.20%)	2,068.5	(0.22%)	-16.0%
-/-	1.A.3.a Transport: Domestic Aviation	All fuels	N_2O	24.6	(0.00%)	20.6	(0.00%)	-16.2%
-/-	1.A.3.a Transport: Domestic Aviation	All fuels	CH_4	2.6	(0.00%)	1.9	(0.00%)	-27.5%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1*, CS (Tier 2)	NS/IS/M	CS, D*
CH_4	CS (Tier 2)	NS/IS/M	CS (M)
N_2O	CS (Tier 2)	NS/IS/M	CS (M)
NO_X, CO	CS (Tier 3)	NS/IS/M	CS (M)
NMVOC	CS (Tier 3)	NS/IS/M	CS (M)
SO_2	Tier 1	NS/IS/M	CS

* biodiesel and co-combusted lubricants

The category *1.A.3.a – Domestic aviation* is not a key category.

In terms of emissions origins, aviation differs considerably from land and water transports, since aircraft burn most of their fuel under changing atmospheric conditions different from those on the ground. The main factors that influence the combustion process in this sector include atmospheric pressure, surrounding temperature and humidity – all of which are factors that vary considerably with flight altitude.

In addition to considering carbon dioxide, the debate on the climate effects and airborne-emissions-related environmental impacts of aviation focuses mainly on water vapour and nitrogen oxides and, secondarily, on hydrocarbons, particulates, carbon monoxide and sulphur dioxide. In the framework of national emissions reporting, figures for other emissions are also required, however. The following remarks thus refer to emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O, laughing gas), nitrogen oxides (NO_X, i.e. NO and NO_2), carbon monoxide (CO), non-methane volatile organic compounds (NMVOC) and sulphur dioxide (SO_2).

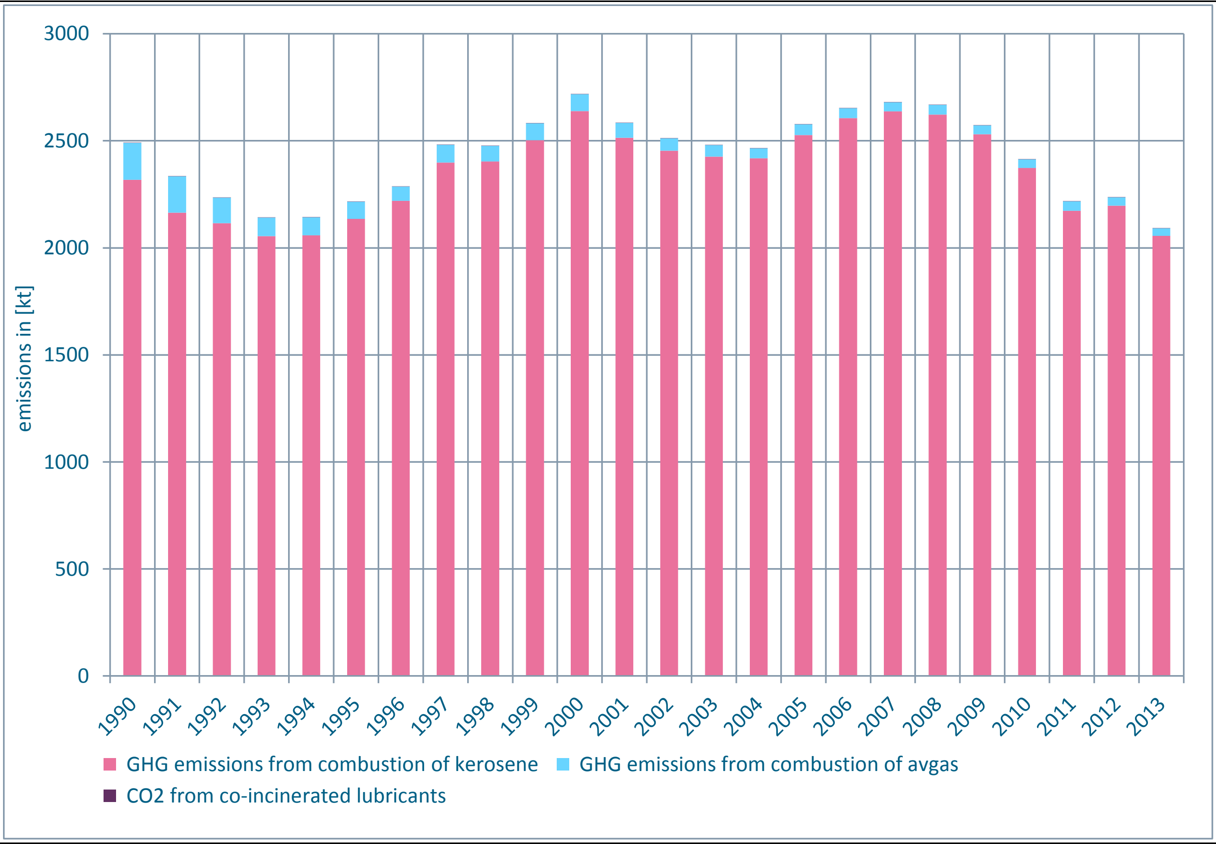

Figure 32: Development of GHG emissions in domestic civil aviation, 1990 – 2013

3.2.10.1.2 Methodological issues (1.A.3.a)

Aviation emissions are calculated in accordance with Tier 3a, i.e. taking account of the annual mileages flown by the relevant individual aircraft types, broken down by national and international flights, and taking account of the operational states LTO cycle (Landing/Take-Off cycle, i.e. aircraft movements to an elevation of 3,000 feet / about 915 m) and cruise (cruising flight at elevations above 3,000 feet).

In general, emissions are determined on the basis of the National Energy Balance data for consumption of kerosene and aviation gasoline (AGEB, 2014). For years for which no data are yet available, data from the Federal Office of Economics and Export Control (BAFA, 2014) are used. For purposes of reporting, civil aviation is broken down into the categories of domestic (intra-German) and international flights. This decisive categorisation is achieved via the domestic flights' shares of the total kerosene consumption as determined within TREMOD AV (TREMOD Aviation) (IFEU & ÖKOINSTITUT 2014). The relevant flight data are collected by the Federal Statistical Office.

For reporting purposes, emissions are determined, in each case, by multiplying fuel consumption for the relevant flight phase by the pertinent specific emission factor. CO_2 and SO_2 emissions figures do not depend on what method is used; they depend solely on the quantities and characteristics of consumed fuel. Emissions of NMVOC, CH_4, CO, NOx and N_2O, on the other hand, depend on engines, flight altitudes, flight phases, etc., and thus they are described more precisely by higher-Tier methods. The emission factors for NOx, CO and HC are thus taken from the results of the TREMOD-AV calculations.

In a departure from this approach, emissions from the consumption of aviation gasoline are calculated separately – as recommended in (IPCC 2006a) – with adapted emission factors and net calorific values, pursuant to the Tier 1 method. In such calculation, there is no need for any breakdown into domestic and international flights as aviation gasoline is used only in smaller aircraft that fly mostly domestic routes.

Activity data

Jet fuel / kerosene

The relevant consumption data accord with the figures for aviation fuel sold in Germany, pursuant to the National Energy Balance (NEB; the latest version, covering the period until 2013) (AGEB, 2014) and to the official mineral-oil data provided by (BAFA, 2014).

The calculations within TREMOD-AV take account of the numbers of flights, for the various aircraft types and great-circle distances involved, for national and international civil aviation. In the process, the commercial flights recorded by the Federal Statistical Office (StaBA), for certain airports, are included. StaBA breaks down flights from "other airfields", and non-commercial flights, only by weight or aircraft classes, but not by destinations. The great majority of the flights concerned are flights by small aircraft fueled with aviation gasoline. Rough calculations pursuant to (IFEU & ÖKOINSTITUT 2010) indicate that it is appropriate to allocate such flights to (solely national) avgas consumption.

Table 28: Domestic (intra-German) flights' share of total domestic kerosene deliveries, in [%]

1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013
16.19	12.35	11.99	9.93	9.745	9.51	9.36	9.30	8.86	8.48	8.00	7.41

Source: TREMOD AV (IFEU & ÖKOINSTITUT, 2014)

Jet-kerosene consumption is also broken down, in accordance with the two flight phases *LTO* and *cruise*, via TREMOD-AV calculations, and on the basis of StaBA data. Those results make it possible to extract kerosene consumption figures for the LTO flight phase for both domestic and international flights. Consumption in the cruise flight phase is obtained as the difference in kerosene consumption, pursuant to the NEB, less the LTO consumption.

Avgas

The relevant consumption data accord with the figures for avgas sold in Germany, pursuant to (AGEB, 2014) and (BAFA, 2014). In a conservative approach, all relevant consumption is assumed to occur in national flight operations. Pursuant to (IPCC 2006a), breakdown by LTO and cruising flight phases is not required.

Co-combusted lubricants

The pertinent quantities of co-combusted lubricants are derived, pursuant to (VSI, 2014), from the relevant annual fuel quantities.

Emission factors

Jet fuel / kerosene

The emission factor for *carbon dioxide* was derived from the carbon content of jet kerosene; it is *3,150 g/kg*. That value, which has been substantiated by numerous published studies, is used for the entire aviation sector.

Nitrous oxide (laughing gas) is a product of nitrogen oxidation in the combustion chamber, and it can occur in traces. The available data for this substance are poor. Since the emission factors have to be broken down in accordance with the two flight phases, the emission factors for both nitrous oxide and *methane* have been taken from the IPCC emission factor database (cf. Table 384).

Other emissions are calculated separately by flight phases, on the basis of the relevant emission factors. In the process, different sources are used.

The data for emissions of NO_X, CO and NMVOC are based on aircraft-type-specific emission factors listed in TREMOD-AV. Those emission factors are used to generate average (implied) emission factors. For reporting purposes, annual average (implied) emission factors are also derived for the entire fleet.

The emissions per LTO cycle are recalculated using standard values for jet-kerosene consumption per LTO cycle: for national flight operations, the relevant figure is 850 kg jet kerosene / LTO, while for international flight operations an average value of 1,675 kg kerosene / LTO is assumed (IPCC 2006b). Figures relative to the air pollutants additionally considered are presented in Chapter 19.1.3.1 in the Annex.

The mass-based emission factors were converted into energy-based emission factors via a net calorific value of 43,000 kJ/kg (AGEB, 2014).

Avgas

For avgas, emission factors do not have to be divided into LTO and cruise categories.

For purposes of calculation of *CO_2 emissions*, the standard value pursuant to (IPCC 2006a) is used. In those guidelines (page 3-64), the emission factors for *methane* and *nitrous oxide* are explicitly defined as equal to the relevant values given for jet-kerosene use. That assumption has been adopted here.

In a procedure similar to that used for jet kerosene, the emission factors for NO_X and CO were obtained from the results of TREMOD-AV calculations carried out with aircraft-type-specific emission factors from the EMEP/EEA database. Those factors were then divided by the relevant avgas consumption, to obtain annual, average emission factors for reporting purposes.

Co-combusted lubricants

The CO_2 emissions from co-combustion of lubricants were calculated pursuant to IPCC-Tier 1, using a default emission factor. With regard to releases of methane and nitrous oxide, it is assumed that such emissions are already taken into account in the pertinent emission factors for the fuels used and thus are to be reported as IE *(included elsewhere)*.

Table 29: EF(CH_4) and EF(N_2O) 2013, in [kg/TJ]; in parentheses: default values pursuant to (IPCC, 2006)

	CH_4	N_2O	Origin
Kerosene			
LTO	8.21 (0.50)	2.74 (2.00)	country-specific values pursuant to TREMOD AV (IFEU & ÖKOINSTITUT, 2014)
Cruise	0.00 (0.50)	2.33 (2.00)	
Avgas	8.21 (-)	2.33 (-)	equivalent to EF for kerosene, CH_4: LTO; N_2O: Cruise
Lubricants	IE	IE	included in the EF for the fuels

Source: (ÖKOINSTITUT, 2014)

3.2.10.1.3 Uncertainties and time-series consistency (1.A.3.a)

For determination of uncertainties, the individual components that enter into emissions calculation are identified, and their uncertainties (U_1 to U_x) are quantified. Pursuant to IPCC GPG (2000), the total uncertainty U_{total} is obtained via additive linking of squared partial uncertainties, in accordance with the following formula:

$$U_{ges} = \sqrt{U_1^2 + U_2^2 + ... + U_n^2}$$

For all time series and flight phases, uncertainties were estimated as mean values. The total uncertainties were calculated as is shown in Annex Chapter 19.1.3.1.2. The left column in that section contains the components that enter into the uncertainty calculation; the relevant partial uncertainties are listed in the neighbouring columns to the right. The columns that then follow to the right contain the values for the required total uncertainties. Some of these, in turn, are individual components of the uncertainties calculation for other values. For example, the uncertainty for national jet-kerosene consumption in the two relevant flight phases, LTO and cruise, is calculated from the partial uncertainties for total national jet-kerosene consumption and from the partial uncertainty for the LTO/cruise breakdown. The latter of these partial uncertainties is based on the number of relevant flights, pursuant to the *Federal Statistical Office*, as well as on assumptions pertaining to the manner in which the fleet is divided (in national flight operations, an average consumption of 850 kg jet kerosene per LTO cycle is applied, in keeping with the IPCC's assumptions). The total uncertainty for kerosene consumption during the LTO and cruise flight phases, in turn, serves as a partial uncertainty in determination of the uncertainties for emissions data.

3.2.10.1.4 Category-specific quality assurance / control and verification (1.A.3.a)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The current calculation procedures have been verified on the basis of more-current data and findings. This applies to the various emission factors used and the energy-content figures required for conversion into energy-related emission factors.

For a growing share of aircraft types for which no specific data are available, emission factors have to be obtained via regressions carried out on the basis of take-off weight. Use of more current, and more complete, aircraft-type-specific data would further improve the quality of the calculations. Furthermore, expansion of the TREMOD-AV calculations, to include differentiation in accordance with the different engines used, would also improve the quality of the calculations.

Except for the emission factors for sulphur dioxide, international standard values were used, taken from the IPCC emission-factors database, the EMEP-EEA database or the EMEP/EEA Guidebook 2013 (EMEP/EEA 2013). Discussions of the various individual values are presented in the "Methodological Aspects" chapters of the presentations of the various emission factors.

Country-specific consumption and emissions data provided by Eurocontrol are currently being used only for verification purposes.

Table 30: Overview of relevant comparisons

Comparison with...	Completed	Remark
alternative emissions inventories for Germany	no	no comparable data records
category-specific Tier 1 default EF pursuant to (IPCC, 2006; Table 3.6.4): CO_2	yes	cf. Table 31
category-specific Tier 1 default EF pursuant to (IPCC, 2006; Table 3.6.5): CH_4, N_2O	yes	cf. Table 29
specific IEF of other countries	yes	cf. Table 32

Table 31: Comparison of the EF(CO_2) used in the inventory with default values

	Inventory value	Default	*Lower bound*	*Upper bound*
Kerosene	73,256	71,500	*69,700*	*74,400*
Avgas	70,000	70,000	*67,500*	*73,000*
Co-combusted lubricants*)	73,300	73,300	*71,900*	*75,200*

2) CO_2 from co-combustion of lubricants is reported under CRF 2.D.1

The following table provides a comparison with specific implied emission factors of other countries.

Table 32: International comparison of reported IEF (all figures in [kg/TJ])

	Kerosene			Avgas		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Germany	73,256	2.55	2.45	70,000	8.21	2.33
Denmark	71,689	24.63	3.21	72,360	18.78	2.00
France	71,591	0.97	2.36	73,000	1.85	2.49
Netherlands	71,500	0.50	2.00	72,000	20.00	0.60
Norway	73,086	2.13	2.32	71,298	8.71	2.28
Switzerland	73,200	6.36	2.33	IE	IE	IE
UK	71,724	0.92	2.28	69,517	16.47	2.22
EU (28)	71,959	1.35	2.36	71,208	10.74	2.35

Germany: current IEF for 2013; all other countries: IEF for 2012, pursuant to 2014 CRF Tables

3.2.10.1.5 Category-specific recalculations (1.A.3.a)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

3.2.10.1.6 Category-specific planned improvements (1.A.3.a)

In future, following routine revision, TREMOD-AV will begin to take account of flight data for all German airports. This will permit more-precise calculation of the share of kerosene consumption to be allocated to domestic flights.

To ensure consistency with the relevant total annual quantities of jet kerosene given by the NEBs, the quantities of kerosene used for international flights will then be calculated by subtracting the quantities used for domestic flights from the total annual NEB quantities.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

3.2.10.2 Transport – Road transportation (1.A.3.b)

3.2.10.2.1 Category description (1.A.3.b)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T/2	**1.A.3.b Transport: Road Transportation**	**All fuels**	**CO_2**	**151,861.0**	**(12.46%)**	**151,347.6**	**(16.19%)**	**-0.3%**
-/T	**1.A.3.b Transport: Road Transportation**	**All fuels**	**CH_4**	**1,316.8**	**(0.11%)**	**146.5**	**(0.02%)**	**-88.9%**
-/-	1.A.3.b Transport: Road Transportation	All fuels	N_2O	1,113.6	(0.09%)	1,426.6	(0.15%)	28.1%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1*, CS (Tier 2)	NS/M	CS, D*
CH_4	Tier 1**, CS (Tier 3)	NS/M	CS (M), D**
N_2O	Tier 1**, CS (Tier 3)	NS/M	CS (M), D**
NO_X, CO, NMVOC, SO_2	CS (Tier 3)	NS/M	CS (M)

* biodiesel, petroleum, co-combusted lubricants, ** liquefied petroleum gas

The category *1.A.3.b – Road transportation* is a key category for CO_2 emissions in terms of level and trend and of Tier 2 analysis. For CH_4 emissions, it is a key category only in terms of trend.

Emissions from motorised road transport in Germany are reported under this category. It includes transport on public roads within Germany, except for agricultural, forestry and military transports. Calculations are made for the vehicle categories of passenger cars (PCs), motorcycles, light duty vehicles (LDVs), heavy duty vehicles (HDVs), buses and motorcycles. For calculation purposes, the vehicle categories are broken down into so-called *vehicle layers* with the same emissions behaviour. To that end, vehicle categories are also broken down by type of fuel used, vehicle size (trucks and buses by weight class; automobiles and motorcycles by engine displacement) and pollution control equipment used, as defined by EU directives for emissions control ("EURO norms"), and by regional traffic distribution (outside of cities, in cities and on motorways).

3.2.10.2.2 Methodological issues (1.A.3.b)

- cf. also Chapter 18.1.3.2 -

Since 1990, emissions of CH_4, NO_X, CO, NMVOC and SO_2 from road transport have decreased sharply, due to catalytic-converter use and engine improvements resulting from continual tightening of emissions laws, and due to improved fuel quality.

Between 1990 and 1993, the methane emission factor for gasoline dropped sharply. This was due especially to a massive reduction in the numbers of vehicles with two-stroke engines in the new German Länder. Further EF decreases have resulted from the aforementioned tightening of emissions standards.

For buses and heavy duty vehicles (over 3.5 t total permissible vehicle weight), maximum permissible levels of hydrocarbon (HC) emissions were lowered considerably (-40 %) via the introduction of the EURO3 standard in 2000. Since EURO3 vehicles were very quick to reach the market as of 2000, the emission factor for hydrocarbon emissions from diesel oil – and the relevant emissions themselves – decreased considerably after 2000. A similar trend occurred for methane, emissions of which are calculated as a fixed share of total HC emissions.

N_2O emissions result primarily from incomplete reduction of NO to N_2 in 3-way catalytic converters. They are not limited by law. Initially, growth in numbers of cars with catalytic converters caused increases in N_2O emissions in comparison to the 1990 level. Newer catalytic converters are optimised to produce only small amounts of N_2O, however. As a result, N_2O decreased during the period 2000-2006. Since then, such emissions have been increasing again. Those increases are due to increasing use of selective catalytic reduction (SCR) equipment in HDVs; under certain conditions, such equipment can produce N_2O as an undesired by-product.

CO_2 emissions depend directly on fuel consumption. From 1990-1999, these emissions increased, since growth in mileage travelled outweighed improvements in vehicle fuel consumption. In the 2000-2009 period, road-transport emissions from consumption of fossil fuels decreased for the first time. The likely reasons for this trend include reductions in specific fuel consumption, the marked shift toward diesel vehicles in new registrations, continual increases in fuel prices, use of biofuels – and consumers' growing tendency to travel to other countries in order to make their fuel purchases (see the following paragraphs).

In the years 2010 and 2011, the emissions increased again, as the aforementioned trends slowed and overall mileage increased. In 2012, they decreased by 1.3 million t with respect to the previous year, however, because traffic volumes and mileage decreased. Then, in 2013, traffic volumes and mileage rebounded, and use of biofuels decreased. These factors caused emissions to increase by more than 4 million t over their level in the previous year. What is more, the average engine performance levels of newly registered automobiles have been increasing for years; this trend has also been driving emissions upward.[28]

[28] According to the Federal Statistical Office (StaBA), the average engine performance of newly registered automobiles in 2013 was 137 hp. The corresponding figure eight years earlier was just under 123 hp. https://www.destatis.de/DE/PresseService/Presse/Pressemitteilungen/2015/06/PD15_213_85pdf.pdf?__blob=publicationFile

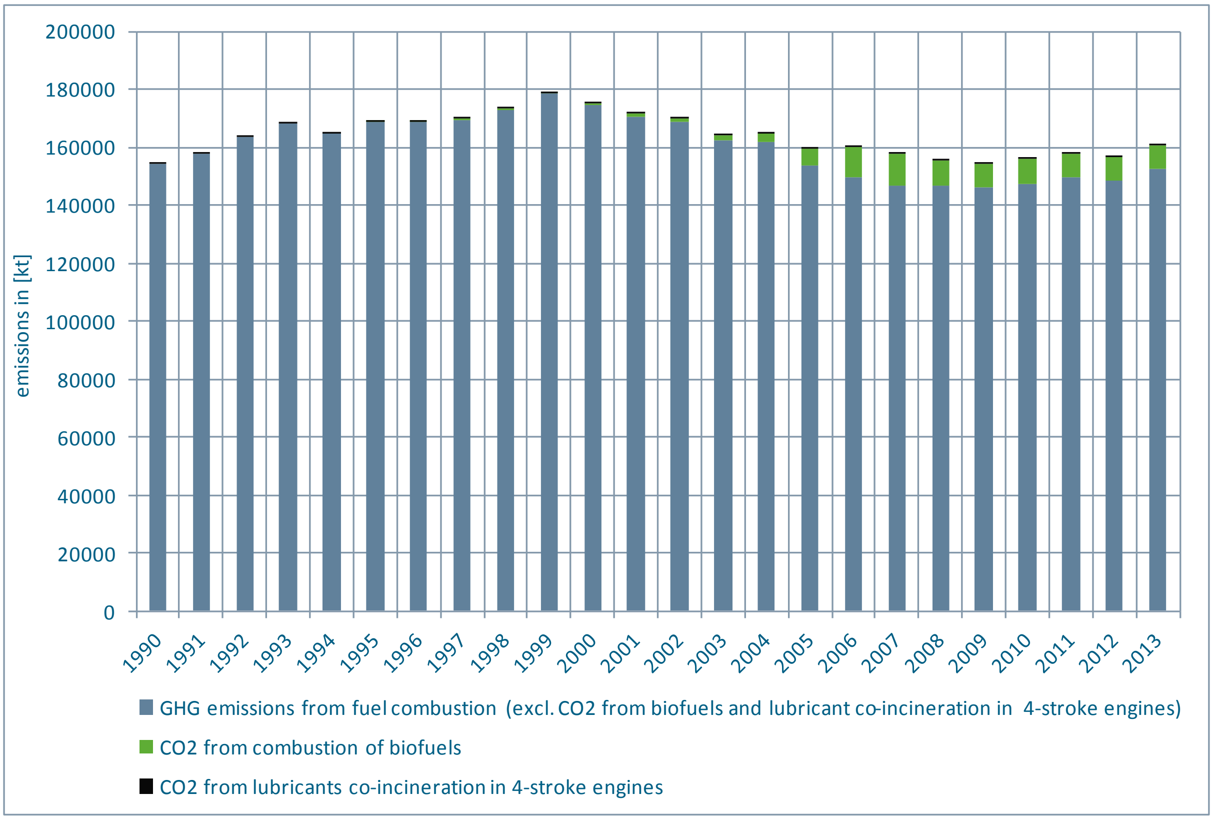

Figure 33: Development of GHG emissions in road transports, 1990 – 2013

CO_2 emissions from motorised road transports in Germany are calculated via a Tier-2 "*bottom-up*" approach pursuant to (IPCC, 2006; page 3.12): In the pertinent process, the fuels sold in Germany (gasoline, (bio-) ethanol fuel, diesel oil, biodiesel, LP and natural gas, petroleum (until 2002)) are allocated, within TREMOD ("Transport Emission Model"), to the various relevant vehicle layers (cf. Chapter 19.1.3.2) (IFEU, 2013)[29]. The consumption data that enter into the model, for each type of fuel, are obtained from the *National Energy Balances* (NEBs). The actual emission calculation is carried out in the Central System of Emissions (CSE), after the pertinent specific fuel consumption data and emission factors have been imported.

The procedure for calculation of non-CO_2 emissions is based on a Tier-3 method, implemented in TREMOD, in which the mileage data for the relevant individual vehicle layers are multiplied by the applicable specific emission factors. For PCs and LDVs, a "*cold start surplus*" is also added. The total consumption determined for each fuel type is cross-checked against consumption pursuant to the NEB. Then, the relevant emissions as calculated in TREMOD are corrected with the help of correction factors obtained via such cross-checking. For gasoline-powered vehicles, the VOC-evaporation emissions are calculated as a function of the pollution-control technology used. From emissions and fuel consumption data for the individual TREMOD vehicle layers, implied emission factors (IEF) in [kg/TJ] are derived. The IEF, fuel-based, are differentiated by fuel type and road type (motorway, country road, municipal streets) and, within the individual vehicle categories, by "with/without" emissions-control equipment. The following categories of emissions-control equipment are differentiated:

[29] To make it possible to derive and assess reduction measures, energy consumption and CO_2 emissions for the various vehicle categories are also calculated with TREMOD. The resulting values are subsequently checked against total consumption and total CO_2 emissions.

Table 33: Differentiation of emissions-control categories in road transports

Vehicle classes considered	Emissions-control system Without	With
PCs / LDVs with gasoline engines	without catalytic converter	with catalytic converter
PCs / LDVs with diesel engines, as well as buses, HDVs and motorcycles	prior to EURO 1	as of EURO 1

The actual emission calculation is carried out in the CSE, after the pertinent specific fuel consumption data and IEF have been imported.

Table 34: Emissions from road transports (all figures in [kt])

	CO_2 fossil[1)]	CO_2 *bio*[2)]	CH_4	N_2O	NO_X	CO	NMVOC[3)]	SO_2
1990	151,861	0.00	52.67	3.74	1,342.65	6,658.02	1,168.53	90.20
1995	166,412	106.48	29.12	5.39	1,136.24	3,469.40	532.39	69.31
2000	172,465	869.14	18.60	5.05	1,034.30	2,157.96	290.94	19.67
2005	152,699	5,573.28	11.18	3.27	738.20	1,373.78	174.55	0.80
2006	148,677	10,176.48	10.13	3.23	713.88	1,246.48	159.72	0.81
2007	145,687	11,004.73	9.10	3.37	650.83	1,133.77	143.09	0.80
2008	145,462	8,914.21	7.91	3.54	570.72	1,029.58	126.17	0.78
2009	145,172	8,024.18	7.34	3.71	519.96	971.18	117.48	0.78
2010	146,227	8,482.69	6.69	4.01	502.31	906.46	108.93	0.79
2011	148,167	8,175.30	6.47	4.28	478.51	883.36	104.97	0.79
2012	146,828	8,420.90	6.00	4.52	463.49	822.80	97.31	0.79
2013	151,348	7,628.56	5.86	4.79	460.76	804.08	94.92	0.81

1) including CO_2 from lubricants co-combusted in two-stroke engines

2) CO_2 emissions from biofuels are listed here solely for informational purposes

3) includes evaporation-related emissions

For calculation with TREMOD, extensive basic data from generally accessible statistics and special surveys are used, co-ordinated, and supplemented. The main data sources used, and key assumptions made, are outlined only briefly here. A detailed description of the databases, including information on the sources used, and the calculation methods used in TREMOD, is provided in (IFEU, 2013a).

For western Germany from 1990 through 1993, and for Germany as a whole as of 1994, total-automobile-fleet data are calculated on the basis of the officially published fleet and new registration statistics of the Federal Motor Transport Authority (KBA). The car ownership analysis for East Germany in 1990 was based on a detailed analysis of the Adlershof car-emissions-testing agency in 1992 and the time series in the statistical annuals of the GDR. For the period between 1991 and 1993, it was necessary to estimate the figures with the aid of numerous assumptions.

The fleet data in the TREMOD model, as of reference years as of 2001, have been obtained by querying the database of the KBA. The supplied data include vehicle fleets for each reference year, broken down as required for emissions calculation, i.e. in accordance with the following characteristics: type of engine (gasoline, diesel oil, other), size class, vehicle age and emissions standard. For each reference year, the mid-year fleet is assumed to be representative of the fleet's composition for the year.

Mileage data are updated on the basis of the "2002 Mileage Survey" ("Fahrleistungserhebung 2002"; IVT, 2004) and the 2010 road transport census (Straßenverkehrszählung 2010; BASt, 2013). For heavy duty vehicles, the data are also cross-checked against road-toll statistics.

With regard to country-specific **emission factors** for CO_2, we refer to Chapter 18.7. For gasoline and natural gas, year-specific values, weighted in accordance with the fuel qualities produced in Germany, are available. For all other fuels, standardised EF(CO_2) are used, throughout all relevant years.

All other emission factors are listed in the "Handbook Emission Factors for Road Transport 3.2" (HBEFA) (INFRAS, 2014), which has been produced via a cooperative effort, involving Germany, Switzerland, Austria and the Netherlands, aimed at deriving emission factors for road transports. In large part, the factors were obtained via measurement programmes of TÜV Rheinland and RWTÜV and via fundamentally oriented studies oriented to the reference years 1989/1990. In those studies, a new method was used, for both passenger cars and heavy duty vehicles, whereby emission factors were derived on the basis of driving habits and traffic situations. Emission factors for automobiles until the 1994 (automobile-)model year were updated with the help of field-monitoring data. HBEFA version 3.2, which is used for the current emissions calculations, draws on findings of the EU working group COST 346 and the ARTEMIS research programme.

The development of the EF(N_2O) reflects the ongoing tightening of emission limit values (ELVs) for NOx, as well as the continuing development of the technologies and exhaust-emissions standards (Euro norms) introduced to ensure compliance with those limit values. Pollution-control equipment, while reducing nitrogen oxide (NOx) emissions overall, has increased nitrous oxide emissions, however.

With regard to co-combustion of lubricants, it is assumed that the pertinent non-CO2 emissions are already included in the emission factors for the relevant fuels and thus have to be reported here as IE (*included elsewhere*).

Increasing "refueling tourism"

Because fuel prices in Germany are higher – significantly, in some cases – than in several of Germany's neighbours, for some time the fuels used in Germany have included fuels purchased in other countries and brought into the country as "grey" imports.

At present, no precise data are available on this phenomenon, which is significant for truck and automobile traffic in Germany's border regions and which is referred to as "refueling tourism" ("Tanktourismus"). Although several detailed studies have been carried out, no reliable overall picture of the situation is available (cf. LENK et al., 2005).

The sources that have documented shifting of consumers' fuel purchases to other countries (along with the resulting negative impacts on neighbouring countries' own emissions inventories) have included a study published by the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW, 2005). The relevant neighbouring countries profit, to a not-inconsiderable degree, from additional revenue from energy taxation of such fuels. Such revenue is likely to be significantly higher than the certificate costs for the pertinent CO_2 emissions would be.

3.2.10.2.3 Uncertainties and time-series consistency (1.A.3.b)

In the framework of a study (IFEU & INFRAS 2009), uncertainties were calculated for the activity data entered into TREMOD, for the emission factors generated in TREMOD and for the emissions calculated in the Central System of Emissions (CSE).

3.2.10.2.4 Category-specific quality assurance / control and verification (1.A.3.b)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

Quality reports of the Working Group on Energy Balances (AGEB) have been submitted to the Federal Environment Agency, for purposes of quality assurance of the National Energy Balances. In addition, documentation on revision of NEBs as of 2003 has been published in the Internet[30].

Table 35: Overview of relevant comparisons

Comparison with...	Completed	Remark
alternative emissions inventories for Germany	no	no comparable data records
category-specific Tier 1 default EF pursuant to (IPCC, 2006; Table 3.2.1): CO_2	no	no Tier 1 default EF for biofuels and petroleum
Tier 1 default EF pursuant to (IPCC, 2006; Table 2.4): CO_2	yes	cf. Table 36
category-specific Tier 2 default EF pursuant to (IPCC, 2006; Table 3.2.2): CH_4, N_2O	yes	results are inconclusive
Tier 1 default EF pursuant to (IPCC, 2006; Table 2.4): CH_4, N_2O	yes	results are inconclusive
specific IEF of other countries	yes	cf. Table 37

Table 36: Comparison of the EF(CO_2) used in the inventory with default values

	Inventory value	Default	*Lower bound*	*Upper bound*
Diesel oil	74,000	74,100	*72,600*	*74,800*
Gasoline	73,091[1)]	69,300	*67,500*	*73,000*
Natural gas	55,917[1)]	56,100	*54,300*	*58,300*
Liquid gas	65,413[1)]	63,100	*61,600*	*65,600*
Petroleum	74,000	-	-	-
Co-combusted lubricants[2)]	73,300	73,300	*71,900*	*75,200*
Biodiesel	70,800	70,800	*59,800*	*84,300*
Bioethanol	71,607	70,800	*59,800*	*84,300*

[1)] value for 2013
[2)] except for two-stroke engines: CO_2 from co-combustion of lubricants is reported under CRF 2.D.1

The following table provides a comparison with specific implied emission factors of other countries as well as with the relevant values resulting for the EU(28).

[30] AG Energiebilanzen (Working Group on Energy Balances): explanations relative to revision of the Energy Balances 2003 – 2009; URL:
http://www.ag-energiebilanzen.de/index.php?article_id=7&clang=0#revision_der_energiebilanzen_2003_bis_2009_05
(last checked on 18 Sept. 2013)

Table 37: International comparison of reported IEF (all figures in [kg/TJ])

	Gasoline			Diesel oil		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Germany	73,091	7.04	0.72	74,000	0.23	3.08
Denmark	72,986	7.43	1.46	73,995	1.15	2.80
France	72,348	16.03	2.26	74,700	1.01	2.70
Netherlands	72,000	10.58	1.30	74,290	0.73	2.39
Norway	71,298	15.98	1.31	73,551	0.35	1.69
Switzerland	73,900	7.34	0.73	73,600	0.29	2.32
UK	69,998	3.08	1.00	72,913	0.87	2.53
EU (28)	71,453	11.17	1.77	73,672	1.23	2.72

Germany: current IEF for 2013; all other countries: IEF for 2012, pursuant to 2014 CRF Tables

3.2.10.2.5 Category-specific recalculations (1.A.3.b)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

3.2.10.2.6 Category-specific planned improvements (1.A.3.b)

In future, following routine revision, TREMOD will begin to take account of the use of bio-methane as a biogenic gaseous fuel.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

3.2.10.3 Transport – Railways (1.A.3.c)

3.2.10.3.1 Source-category description (1.A.3.c)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T	**1.A.3.c Transport: Railways**	**All fuels**	**CO_2**	**2,899.5**	**(0.24%)**	**998.9**	**(0.11%)**	**-65.5%**
-/-	1.A.3.c Transport: Railways	All fuels	N_2O	7.1	(0.00%)	2.7	(0.00%)	-62.0%
-/-	1.A.3.c Transport: Railways	All fuels	CH_4	2.8	(0.00%)	0.6	(0.00%)	-76.8%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1*, CS (Tier 2)	NS	CS, D*
CH_4	CS (Tier 2)	NS	CS, D**
N_2O	CS (Tier 2)	NS	CS
NO_X, CO, NMVOC, SO_2	CS (Tier 2)	NS	CS

* biodiesel and co-combusted lubricants, ** diesel: pursuant to (EMEP/EEA, 2013)

The category *1.A.3.c – Railways* is a key category for CO_2 emissions in terms of emissions level and trend.

Germany's railway sector is undergoing a long-term modernisation process, aimed at making electricity the main energy source for rail transports. Electricity now provides about 81 % of all railway traction power[31]. Railways' power stations for generation of required traction current are allocated to the stationary component of electricity generation in public power stations (1.A.1.a) and are not included in the following section.

In energy input for trains operating in Germany, diesel oil is the only energy source that plays a significant role apart from electric power. Since 2004, biodiesel has also been used, as an additive.

In historic vehicles, very small quantities of solid fuels are also used. The National Energy Balances (NEBs) provide pertinent evaluatable consumption data for lignite, for the period until 2002, and for hard coal, for the period until 2000 (AGEB, 2014).

Use of other fuels – such as vegetable oils or gas – in private narrow-gauge railway vehicles has not been included to date and may be considered negligible.

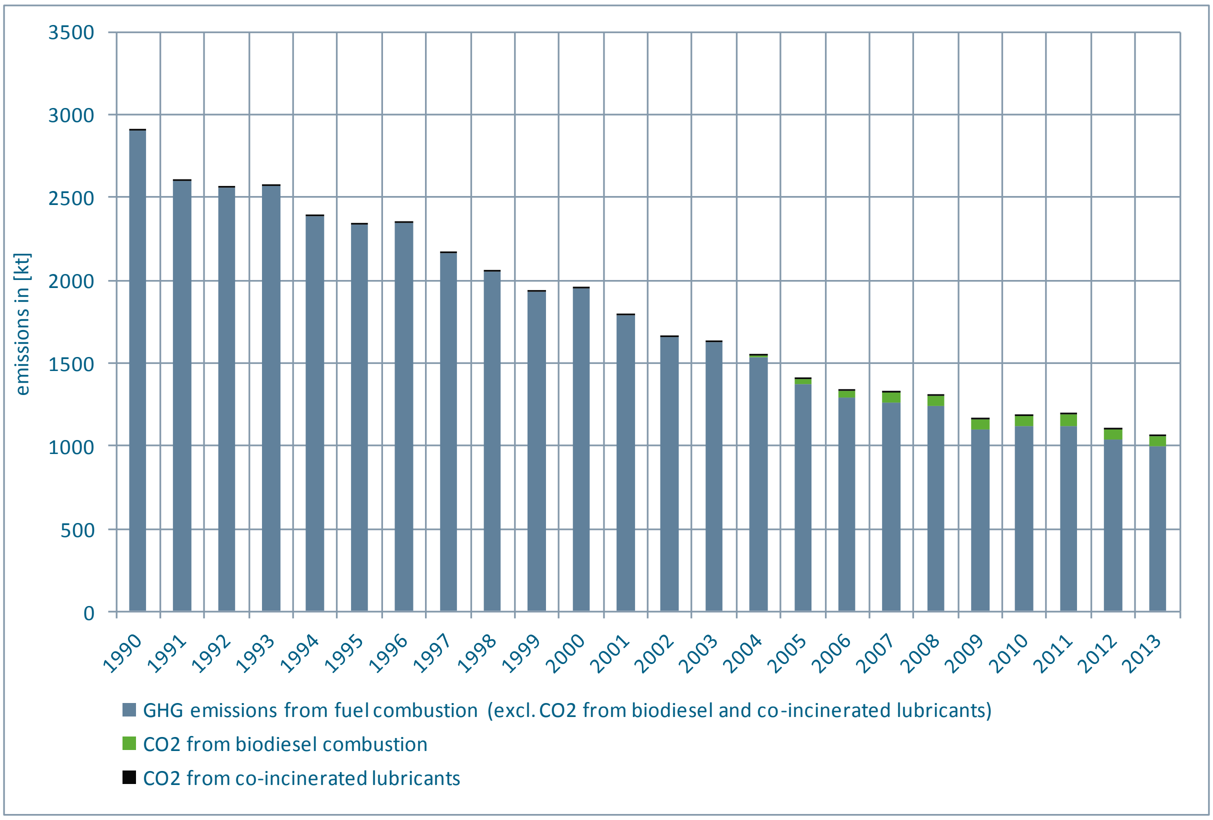

Figure 34: Development of GHG emissions from railway transports, 1990-2013 (*not including emissions from generation of electric power for railways*)

3.2.10.3.2 Methodological issues (1.A.3.c)

The relevant emissions are thus calculated as the product of fuel consumption and the relevant country-specific emission factors. This procedure conforms to the general Tier 2 method and the basic calculation rule pursuant to Equation 3.4.2 of the 2006 IPCC Guidelines (page 3.42).

Activity data:

As a rule, energy consumption data are taken from NEB lines 74 (through 1994) and 64 (as of 1995) (AGEB, 2014). In a departure from that source, for methodological reasons, figures for the years 2005 through 2009 are based on sales data of the *Association of the German*

[31] "Verkehr in Zahlen 2013/2014"

Petroleum Industry (MWV) published in the annual report *"Petroleum Data" ("Mineralöl-Zahlen")* (and presented in the Table *"sectoral consumption of diesel oil" ("Sektoraler Verbrauch von Dieselkraftstoff")* (MWV, 2014).

Due to inadequacies in the available statistical data, annual figures for biodiesel consumption continue to be calculated on the basis of the official mixture percentages.

Since the NEB data for solid fuels are incomplete, the present report also relies on results of a relevant survey conducted in 2012 (PROBST & CONSORTEN, 2012).

The pertinent quantities of co-combusted lubricants are derived, pursuant to (VSI, 2014), from the relevant consumption of diesel oil (including biodiesel).

Table 38: Overview of the statistics and other sources used

Fuel	Source(s) used
Diesel oil	1990-2004: AGEB / 2005-2009: MWV / as of 2010: AGEB
Biodiesel	calculated in keeping with official admixture quotas
Hard coal	1990-1994: AGEB / as of 2005-2010: Survey / in between, via interpolation / as of 2011, annual updating
Hard-coal coke	1990-1997: AGEB / as of 2005-2010: Survey / in between, via interpolation / as of 2011, annual updating
Raw lignite	as of 1990: AGEB
Lignite briquettes	as of 1990: AGEB
Co-combusted lubricants	pursuant to (VSI, 2104), calculated on the basis of the pertinent total quantity of liquid fuels

Emission factors:

With regard to the CO_2 emission factors used, we refer to Chapter 18.7.

For methane and nitrous oxide, country-specific values pursuant to (IFEU, 2014) and (UBA, 1989b) are used. With regard to releases of these two greenhouse gases from co-combustion of lubricants, it is assumed that such emissions are already taken into account in the pertinent emission factors for the fuels used and thus are to be reported as IE *(included elsewhere)*.

Table 39: Emission factors used for report year 2013; figures in [kg/TJ]; in parentheses: Default values pursuant to (IPCC, 2006)

	CH_4	N_2O	Origin
Diesel oil	1.51 (4.15)	0.56 (28.60)	CH_4: CS value pursuant to (IFEU, 2014a); N_2O: Tier-1 default pursuant to (EMEP/EEA 2013)[32]
Biodiesel	1.51 (-)	0.56 (-)	equivalent to the EF for diesel oil
Lignite briquettes	NO	NO	
Raw lignite	NO	NO	
Hard coal	15.00 (-)	4.00 (-)	cf. (UBA, 1989b)
Hard-coal coke	0.50 (-)	4.00 (-)	cf. (UBA, 1989b)
Co-combusted lubricants	IE	IE	included in the EF for fuels

3.2.10.3.3 Uncertainties and time-series consistency (1.A.3.c)

In the framework of a study (IFEU & INFRAS 2009), uncertainties were calculated for the activity data entered into TREMOD, for the emission factors generated in TREMOD and for the emissions calculated in the Central System of Emissions (CSE).

[32] The default value pursuant to (IPCC, 2006), amounting to 28.6 kg/TJ, is now considered outdated, and is not used in the present report, because the cited original source (EMEP/CORINAIR: Emission Inventory Guidebook – 2005) has since been revised.

The activity-rate time series for lignite briquettes, hard coal and hard-coal coke exhibit inconsistencies resulting from statistical conversion as of 1994/1995; these inconsistencies cannot be eliminated at present.

3.2.10.3.4 Category-specific quality assurance / control and verification (1.A.3.c)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

Quality reports of the Working Group on Energy Balances (AGEB) have been submitted to the Federal Environment Agency, for purposes of quality assurance of the National Energy Balances. In addition, documentation on revision of NEBs as of 2003 has been published in the Internet[33].

Table 40: Overview of relevant comparisons

Comparison with...	Completed	Remark
alternative emissions inventories for Germany	no	no comparable data records
category-specific Tier 1 default EF pursuant to (IPCC, 2006): CO_2	yes	Tier 1 default EF not for all relevant fuels
Tier 1 default EF pursuant to (IPCC, 2006; Table 2.4): CO_2	yes	cf. Table 36
category-specific Tier 1 default EF pursuant to (IPCC, 2006): CH_4, N_2O	yes	cf. Table 39
Tier 1 default EF pursuant to (IPCC, 2006; Table 2.4): CH_4, N_2O	yes	results are inconclusive
specific IEF of other countries	yes	cf. Table 42

Table 41: Comparison of the EF(CO_2) used in the inventory with default values

	Inventory value	Default	*Lower bound*	*Upper bound*
Diesel oil	74,000	74,100	*72,600*	*74,800*
Lignite briquettes	99,096[1)]	97,500	*87,300*	*109,000*
Raw lignite	105,136[1)]	101,000	*90,900*	*115,000*
Hard coal	93,363[1)]	94,600	*89,500*	*99,700*
Hard-coal coke	108,130[1)]	107,000	*95,700*	*119,000*
Co-combusted lubricants[2)]	73,300	73,300	*71,900*	*75,200*
Biodiesel	70,800	70,800	*59,800*	*84,300*

[1)] value for 2013

[2)] CO_2 from co-combustion of lubricants is reported under CRF 2.D.1

The following table provides a comparison with specific implied emission factors of other countries as well as with the relevant values resulting for the EU(28).

[33] AG Energiebilanzen (Working Group on Energy Balances): explanations relative to revision of the Energy Balances 2003 – 2009; URL: http://www.ag-energiebilanzen.de/index.php?article_id=7&clang=0#revision_der_energiebilanzen_2003_bis_2009_05 (last checked on 4 Oct. 2014)

Table 42: International comparison of reported IEF (all figures in [kg/TJ])

	Fossil liquid fuels			Fossil solid fuels		
	CO_2	CH_4	N_2O	CO_2)	CH_4	N_2O
Germany	74,000	1.51	0.56	93,000	14.97	4.00
Denmark	74,000	2.17	2.04	NO	NO	NO
France	74,700	4.30	1.50	NO	NO	NO
Netherlands	74,300	5.00	0.60	NO	NO	NO
Norway	73,550	4.18	27.84	NO	NO	NO
Switzerland	73,600	0.80	3.11	NO	NO	NO
UK	74,149	3.26	0.56	105,970	99.89	0.80
EU (28)	73,882	3.62	4.77	105,851	98.87	0.86

Germany: current IEF for 2013; all other countries: IEF for 2012, pursuant to 2014 CRF Tables

3.2.10.3.5 Category-specific recalculations (1.A.3.c)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

3.2.10.3.6 Category-specific planned improvements (1.A.3.c)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

3.2.10.4 Transport – Domestic navigation (1.A.3.d)

3.2.10.4.1 Source-category description (1.A.3.d)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T	**1.A.3.d Transport: Domestic navigation**	**All fuels**	**CO_2**	**3,643.6**	**(0.30%)**	**1,747.7**	**(0.19%)**	**-52.0%**
-/-	1.A.3.d Transport: Domestic navigation	All fuels	N_2O	33.6	(0.00%)	17.8	(0.00%)	-46.8%
-/-	1.A.3.d Transport: Domestic navigation	All fuels	CH_4	1.9	(0.00%)	0.7	(0.00%)	-65.6%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1*, CS (Tier 2)	NS/IS/M	CS, D*
CH_4	CS (Tier 2)	NS/IS/M	CS (M)
N_2O	CS (Tier 2)	NS/IS/M	CS (M)
NO_X, CO, NMVOC, SO_2	CS (Tier 2)	NS/IS/M	CS (M)

* biodiesel and co-combusted lubricants

The category *1.A.3.d – Domestic navigation* is a key category for CO_2 emissions in terms of emissions level and trend.

Domestic navigation is broken down into the categories "national maritime transports" and "national inland navigation". Emissions from international navigation are listed in the emissions inventories, as a memo item, but they are not included in total emissions.

In the CSE, both inland navigation and national ship transports between German ports are assigned to category 1.A.3.d – national maritime transports.

The following figure shows the development of greenhouse-gas emissions from domestic ship transports, since 1990, via a breakdown into inland navigation and national maritime transports.

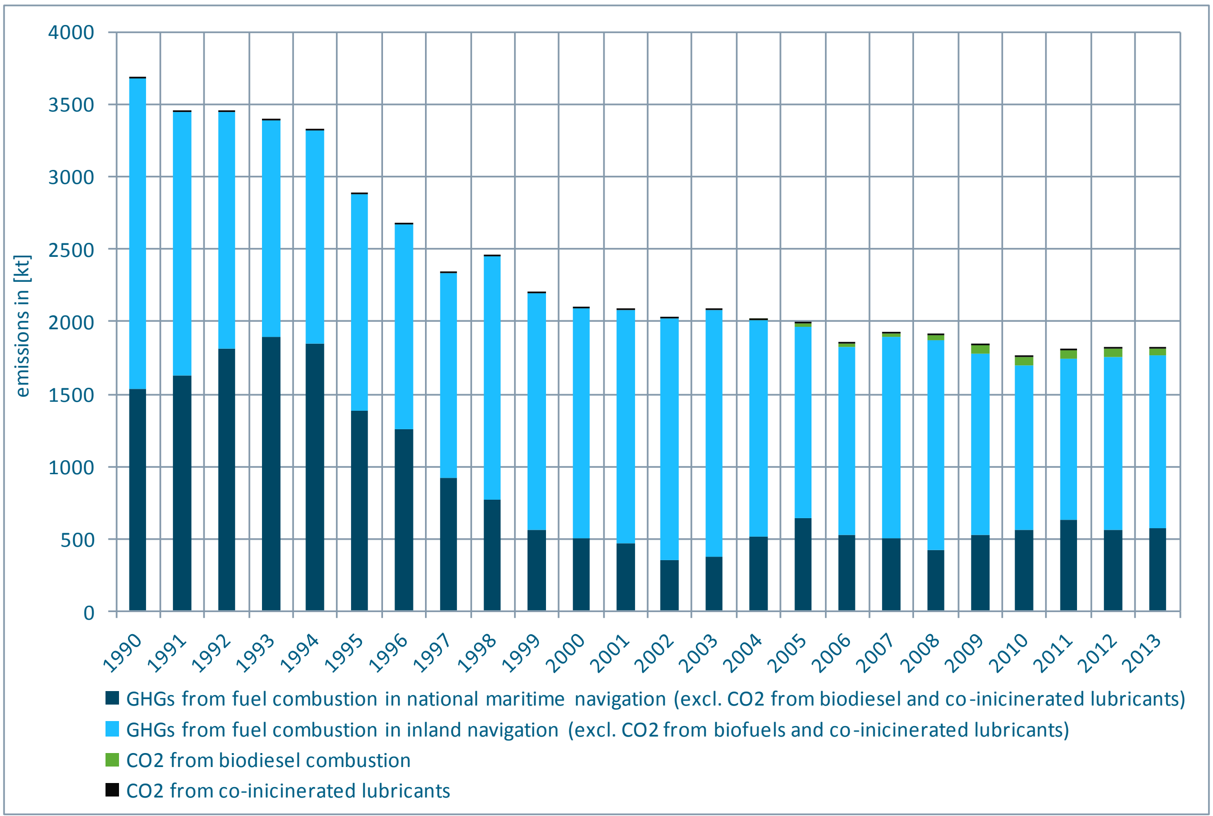

Figure 35: Development of GHG emissions from inland navigation and national ship transports, 1990 – 2013

3.2.10.4.2 Methodological issues (1.A.3.d)

For *national maritime transports*, all primary input data are combined, in keeping with the Tier-3 method pursuant to (IPCC, 2006), in a model developed by the *Federal Maritime and Hydrographic Agency* (BSH). The underlying AIS data used in the process are currently available only as of the year 2010. For the period 1990 through 2009, the specific consumption fractions for national and military maritime transports, and for fisheries, have been derived on the basis of annual trends in relevant indicators (including traffic management data for the Kiel Canal; data on development of military and fishery fleets).

For *national inland navigation*, primary data are combined, via a Tier 2 method, in TREMOD (IFEU 2014a). The model integrates emission values from test-bench measurements as well as data on specific energy consumption aspects. The latter data have been linked with a traffic-quantity model based on the Federal Statistical Office's statistics on inland navigation, and they can be broken down by ship types and sizes, loads and water-body types.

Activity data:

In general, the source for the fuel-quantity data used, as well as for the data for the entire energy sector 1.A, is the National Energy Balance (AGEB, 2014). That source is based extensively on data provided by the MWV and BAFA. The data for the years 2005 through 2009 are based on sales data of the MWV, which differ from the pertinent data in the NEB, and which are published in the annual report "Petroleum Data" (*"Mineralöl-Zahlen"*; in this case: page 52, Table *"Sectoral consumption of diesel oil"* (*"Sektoraler Verbrauch von Dieselkraftstoff"*)) (MWV, 2014). Data on the annual quantities of lubricants sold are taken from the official mineral-oil data (*"Amtliche Mineralöldaten"*) from (BAFA, 2014).

Both AGEB and BAFA divide the data into the categories *domestic* (AGEB: "Coastal and inland navigation" = BAFA: *"an die Binnenschifffahrt" ("for inland shipping")*) and *international* (AGEB: "high-seas bunkering" = BAFA: *"Bunker int. Schifffahrt"*), in keeping with the different taxation rates applied to different ship fuels.

With respect to ship transports, the NEB – as described, solely on the basis of taxation aspects – differentiates between international marine bunkers (NEB line 6) and coastal and inland navigation (NEB line 64). NEB line 6 lists the fuel quantities bunkered by ocean-going ships registered by the *International Maritime Organization* (IMO). This category includes cargo, fishing and military ships that can operate on both national (between two German seaports) and international routes (from Germany to international ports). NEB line 64, on the other hand, lists the fuel quantities that were a) taken on by inland vessels or b) bunkered by ocean vessels that have *not* been registered by the IMO (a category that includes smaller vessels that operate only on national routes). For the breakdown into national and international *maritime* transports, therefore, the fuel quantities listed in NEB line 6 have to be divided in accordance with the categories of nationally operating and internationally operating ocean-going ships. In addition, those relevant specific quantities of fishing and military ships that are reported separately under 1.A.4.c iii and 1.A.5.b iii are deducted.

Table 43: Sources for the activity data used

Material	Source statistics	Location within the source	
Diesel oil and & heavy fuel oil	NEB	line 77 (for the period until 1994) line 64 (for the period as of 1995)	Coastal and inland navigation
Biodiesel	NEB	line 64 (for the period as of 2004)	
Lubricants	calculated on the basis of the total quantity of liquid fuels		

National maritime transports

The annual activity data for national maritime transports consists of the data for the *non*-IMO ocean-going vessels listed in NEB line 64 and of the data for the nationally operating IMO-certified seagoing vessels listed in NEB line 6 (in each case, less the figures for fisheries and military). To determine these fractions, the specific consumption figures of the nationally operating seagoing vessels are calculated – in the aforementioned BSH model – on the basis of their AIS signals (currently, as of 2010; see above) and then aggregated into annual total quantities. Since the model differentiates between IMO- and non-IMO vessels, the sub-quantities listed in NEB lines 6 and 64 are available. By deducting the former of the two sub-quantities (fuel inputs in nationally operating IMO-registered ocean-going vessels) from the bunkered quantities listed in NEB line 6, one obtains a quantity, bunkered by internationally operating ocean-going vessels in Germany, that serves as a basis for calculating the separately listed emissions for international maritime transports (leaving from Germany) pursuant to Tier 1 (cf. Chapter 3.2.2.3).

National inland navigation

The fuel quantities taken on annually by inland vessels in Germany are obtained by deducting the second sub-quantity (fuel inputs in nationally operating, ocean-going non-IMO vessels) from the total quantity listed in NEB line 64. As a result of variations in the navigability of inland waterways, the annual fuel consumption levels of inland ships vary widely. Since the mid-1990s, those levels have been tending to decrease, as many ships have been refueling abroad in order to take advance of lower prices. The abrupt decrease that occurred in 1994/1995 was due to a conversion in the National Energy Balance, however. Due to inadequacies in the available statistical data, annual figures for biodiesel consumption continue to be calculated on the basis of the official admixture percentages.

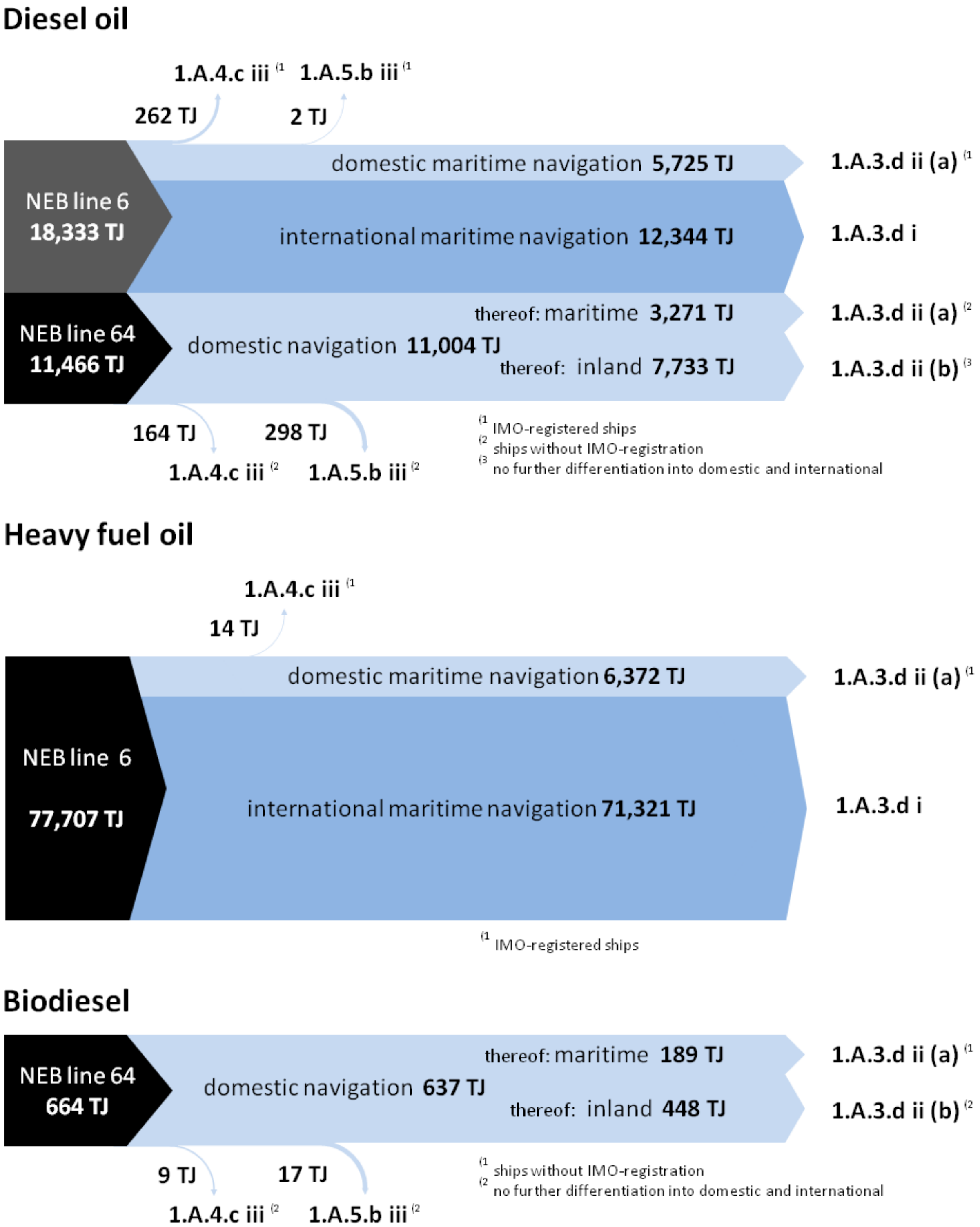

Figure 36: Sectoral division of quantities of diesel oil, heavy fuel oil and biodiesel sold in 2013, pursuant to NEB lines 6 & 64

In the framework of the UNFCCC's review process, Germany has been repeatedly requested (most recently, during the 2014 Centralized Review), to prepare separate figures relative to emissions from international ship transports on the major German rivers (Rhine, Danube, and others). At present, the available data do not allow differentiation of river-going ships (on the Rhine, for example) in terms of their ports of origin and nationalities. Such differentiation could only be provided on the basis of a new annual survey that would require enormous investments of time and resources. Because the relevant emissions can be expected to account for only a very small share of total emissions, such investments are not justified. For this reason, this proposal will not be acted on in Germany in the foreseeable future.

Emission factors:

With regard to the CO_2 emission factors used, we refer to Chapter 18.7.

With regard to releases of these two greenhouse gases from co-combustion of lubricants, it is assumed that such emissions are already taken into account in the pertinent emission factors for the fuels used and thus are to be reported as IE *(included elsewhere)*.

National maritime transports

The emission factors are taken from (BSH, 2015).

National inland navigation

The CH_4 emission factors have been taken from (IFEU, 2014a). They are calculated on the basis of test-bench measurements, and on data, relative to the required propulsion energy, broken down by ship types and sizes, loads and waterway types.

The emission factors for N_2O are in keeping with Federal Environment Agency (UBA) experts' assessments based on the UBA study "Air Quality Control '88" ("Luftreinhaltung '88") and on analogies to heavy duty vehicles without emissions-control equipment.

Table 44: EF(CH_4) and EF(N_2O) 2013, in [kg/TJ]; in parentheses: default values pursuant to (IPCC, 2006)

	CH_4	N_2O	Origin
National inland navigation			
Diesel oil	1.35 (-)	1.00 (-)	country-specific value pursuant to (IFEU, 2014a)
Biodiesel	1.35 (-)	1.00 (-)	equivalent to the EF for diesel oil
National maritime transports			
Diesel oil	0.81 (7.00)	3.29 (2.00)	pursuant to (BSH, 2015)
Biodiesel	0.81 (-)	3.29 (-)	equivalent to the EF for diesel oil
Heavy fuel oil	1.02 (7.00)	3.39 (2.00)	pursuant to (BSH, 2015)
Overarching			
Co-combusted lubricants	IE	IE	Included in the EF for the individual fuels

3.2.10.4.3 Uncertainties and time-series consistency (1.A.3.d)

While it was possible to obtain the uncertainties for national inland navigation from (IFEU & INFRAS, 2009), it is still necessary to apply the IPCC default uncertainties for the area of national maritime navigation.

The activity-data time series for coastal and inland shipping exhibit inconsistencies, resulting from the Energy-Balances transition between 1994 and 1995, that cannot be eliminated at present.

The emission-factor time series exhibit no inconsistencies.

3.2.10.4.4 Category-specific quality assurance / control and verification (1.A.3.d)

For the current submission, due to an absence on the part of the relevant sectoral expert, no quality control and quality assurance was carried out for the area of domestic maritime navigation. General quality control, and quality assurance in conformance with the requirements of the QSE manual and its associated applicable documents, have been carried out by the Single National Entity. Data were taken from previous years or determined on the basis of existing calculation routines.

General quality control and, for the emission factors and emissions data, category-specific quality control, and quality assurance, have been carried out for the area of inland navigation (national inland navigation), in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

Quality reports of the Working Group on Energy Balances (AGEB) have been submitted to the Federal Environment Agency, for purposes of quality assurance of the National Energy Balances. In addition, documentation on revision of NEBs as of 2003 has been published in the Internet[34].

Table 45: Overview of relevant comparisons

Comparison with...	Completed	Remark
alternative emissions inventories for Germany	no	no comparable data records
category-specific Tier 2 default EF pursuant to (IPCC, 2006; Table 3.5.2): CO_2	yes	cf. Table 46
category-specific Tier 3 default EF pursuant to (IPCC, 2006; Table 3.5.3): CH_4, N_2O	(yes)	sea: cf. Table 44 inland: no defaults
Tier 1 default EF pursuant to (IPCC, 2006; Table 2.4): CH_4, N_2O	yes	inland: results are inconclusive
specific IEF of other countries	yes	cf. Table 47

Table 46: Comparison of the EF(CO_2) used in the inventory with default values

	Inventory value	Default	*Lower bound*	*Upper bound*
Diesel oil	74,000	74,100	*72,600*	*74,800*
Heavy fuel oil	80,007[1)]	77,400	*75,500*	*78,800*
Co-combusted lubricants[2)]	73,300	73,300	*71,900*	*75,200*
Biodiesel	70,800	70,800	*59,800*	*84,300*

1) value for 2013

2) CO_2 from co-combustion of lubricants is reported under CRF 2.D.1

The following table provides a comparison with specific implied emission factors of other countries as well as with the relevant values resulting for the EU(28).

[34] AG Energiebilanzen (Working Group on Energy Balances): explanations relative to revision of the Energy Balances 2003 – 2009; URL: http://www.ag-energiebilanzen.de/index.php?article_id=7&clang=0#revision_der_energiebilanzen_2003_bis_2009_05 (last checked on 18 Sept. 2013)

Table 47: International comparison of reported IEF (all figures in [kg/TJ])

	Diesel oil			Heavy fuel oil		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Germany	74,000	1.12	2.22	78,000	1.02	3.39
Denmark	73,892	2.07	4.04	77,972	2.01	4.48
France	74,786	3.40	1.50	78,000	1.25	1.75
Netherlands	74,300	5.00	0.60	NO	NO	NO
Norway	73,550	6.05	1.78	78,818	5.67	1.97
Switzerland	73,617	0.75	2.61	NO	NO	NO
UK	73,913	1.16	1.86	78,323	1.22	1.94
EU (28)	73,605	3.63	3.48	77,113	5.82	2.13

Germany: current IEF for 2013; all other countries: IEF for 2012, pursuant to 2014 CRF Tables

3.2.10.4.5 Category-specific recalculations (1.A.3.d)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

3.2.10.4.6 Category-specific planned improvements (1.A.3.d)

The BSH model is undergoing various types of maintenance work, in the framework of an updating process. Such work cannot be specified at present, however.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

3.2.10.5 Transport – Other transportation (1.A.3.e)

3.2.10.5.1 Category description (1.A.3.e)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/-	1.A.3.e Transport: Other Transportation	All fuels	CO_2	1,086.8	(0.09%)	1,471.2	(0.16%)	35.4%
-/-	1.A.3.e Transport: Other Transportation	All fuels	N_2O	14.5	(0.00%)	12.8	(0.00%)	-11.6%
-/-	1.A.3.e Transport: Other Transportation	All fuels	CH_4	5.3	(0.00%)	7.2	(0.00%)	35.0%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	ETS	CS
CH_4	Tier 2	ETS	CS
N_2O	Tier 2	ETS	CS

The *category 1.A.3.e - Transport – other transportion* is not a key category

Reporting in category 1.A.3.e – Other transport includes only emissions from gas turbines in natural-gas compressor stations of the transport network. The emissions from gas turbines of pumping stations are reported in category 1.A.1.c. Fugitive emissions from compressors are reported under 1.B.2.b.iii & iv. Additional gas compressors are operated in the chemical industry. In keeping with the relevant statistical structure, they are reported in category 1.A.2.g Other.

3.2.10.5.2 Methodological issues (1.A.3.e)

Activity data:

Calculation of fuel inputs for natural gas compressors was completely revised for the NIR 2012. As of 2005, the fuel inputs reported for purposes of emissions trading, and aggregated by the emissions-trading authority, are being used directly, as a new data source. In this area, the only data used from that data set are the data for natural gas compressors that are allocated to the transport network. Natural gas compressors of pumping stations are identified via energy statistics and thus are already included in category 1.A.1.c. This allocation approach prevents double-counting in the inventory.

In light of the new data situation, it seemed likely that the fuel inputs used were too low, throughout the entire time series. Only the value shown in the 2002 Energy Balance seemed plausible. While fuel inputs for natural gas compressors in the period 1995-2002 were reported in the context of statistics, it may be assumed that the recorded levels were too low. To establish consistency in the relevant time series, therefore, recalculations back to 1990 were carried out. Since the relevant fuel inputs fluctuate annually, in keeping with primary energy consumption, simple interpolation would not have led to the desired consistency. For that reason, a mean for the pertinent relationship (fuel inputs / primary energy consumption) was calculated for the period 2005-2009, and then that mean was used for the calculations back to 1990. This procedure has produced a plausible and consistent time series.

Emission factors:

The emission factors for natural-gas use in **natural gas compressor stations** are based, for each specific gas, on the results of various Federal Environment Agency research projects and expert opinions:

- With regard to CO_2, the reader's attention is called to the documentation in Annex 2, the Chapter "CO_2 emission factors".
- The CH_4 and N_2O EF have been obtained from the report FICHTNER et al (2011). The procedure used in the studies is described in Chapter 3.2.6.2.

3.2.10.5.3 Uncertainties and time-series consistency (1.A.3.e)

Uncertainties for the activity data were determined for the first time in the 2004 report year (research project 204 41 132, UBA). The method for determining the uncertainties is described in Annex 2, in the Chapter "Uncertainties in the activity data of stationary combustion plants", of the NIR 2007.

The procedure for determining uncertainties for the EF of natural gas compressor stations is described in Chapter 3.2.6.2. Results for N_2O are presented in Chapter 3.2.6.3.2, while those for CH_4 are presented in Chapter 3.2.6.3.3.

3.2.10.5.4 Category-specific quality assurance / control and verification (1.A.3.e)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The results of Chapter 3.2.6.4 apply mutatis mutandis.

3.2.10.5.5 Category-specific recalculations (1.A.3.e)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

3.2.10.5.6 Category-specific planned improvements (1.A.3.e)

No further improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

3.2.11 Other: Residential, commercial/institutional, agriculture, forestry and fisheries (1.A.4 Stationary)

3.2.11.1 Category description (1.A.4 Stationary)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T/2	**1.A.4.a Other Sectors: Commercial/institutional**	**All fuels**	**CO_2**	**64,198.5**	**(5.27%)**	**40,557.1**	**(4.34%)**	**-36.8%**
-/T	1.A.4.a Other Sectors: Commercial/institutional	All fuels	CH_4	1,449.4	(0.12%)	45.0	(0.00%)	-96.9%
-/-	1.A.4.a Other Sectors: Commercial/institutional	All fuels	N_2O	145.4	(0.01%)	91.9	(0.01%)	-36.8%
L/T/2	**1.A.4.b Other Sectors: Residential**	**All fuels**	**CO_2**	**128,638.2**	**(10.55%)**	**102,892.4**	**(11.00%)**	**-20.0%**
-/-/2	1.A.4.b Other Sectors: Residential	All fuels	CH_4	1,445.3	(0.12%)	750.8	(0.08%)	-48.1%
-/-	1.A.4.b Other Sectors: Residential	All fuels	N_2O	768.9	(0.06%)	346.1	(0.04%)	-55.0%
L/T/2	**1.A.4.c Other Sectors: Agriculture/Forestry/Fisheries**	**All fuels**	**CO_2**	**10,261.5**	**(0.84%)**	**5,651.5**	**(0.60%)**	**-44.9%**
-/-	1.A.4.c Other Sectors: Agriculture/Forestry/Fisheries	All fuels	CH_4	236.3	(0.02%)	570.0	(0.06%)	141.2%
-/-	1.A.4.c Other Sectors: Agriculture/Forestry/Fisheries	All fuels	N_2O	61.5	(0.01%)	85.0	(0.01%)	38.2%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1*, CS	NS/M	CS, D*
CH_4	CS (Tier 2)	NS/M	CS (M)
N_2O	CS (Tier 2)	NS/M	CS (M)
NO_X, CO, NMVOC, SO_2	CS (Tier 2)	NS/M	CS (M)

* biodiesel and co-combusted lubricants

The stationary and mobile sources categories in 1.A.4 are placed in the relevant main categories together. The category 1.A.4 *Other* is a key category for CO_2 emissions, in terms of both emissions level and trend, in all of its sub - categories. In addition, 1.A.4.b is a category for CH_4, (solely) pursuant to Tier 2 analysis.

Category 1.A.4 stationary comprises combustion systems in the areas *Commercial and Institutional, Residential* and *Agriculture*.

Heat-generation systems in small combustion systems of small commercial and institutional users are reported in sub- category 1.A.4.ai Commercial and institutional.

Emissions from residential combustion systems are reported in sub- category 1.A.4.bi. Sub-category 1.A.4.ci comprises the areas of agriculture, forestry and fisheries. Reporting under this category includes emissions from heat generation in small and medium-sized combustion systems.

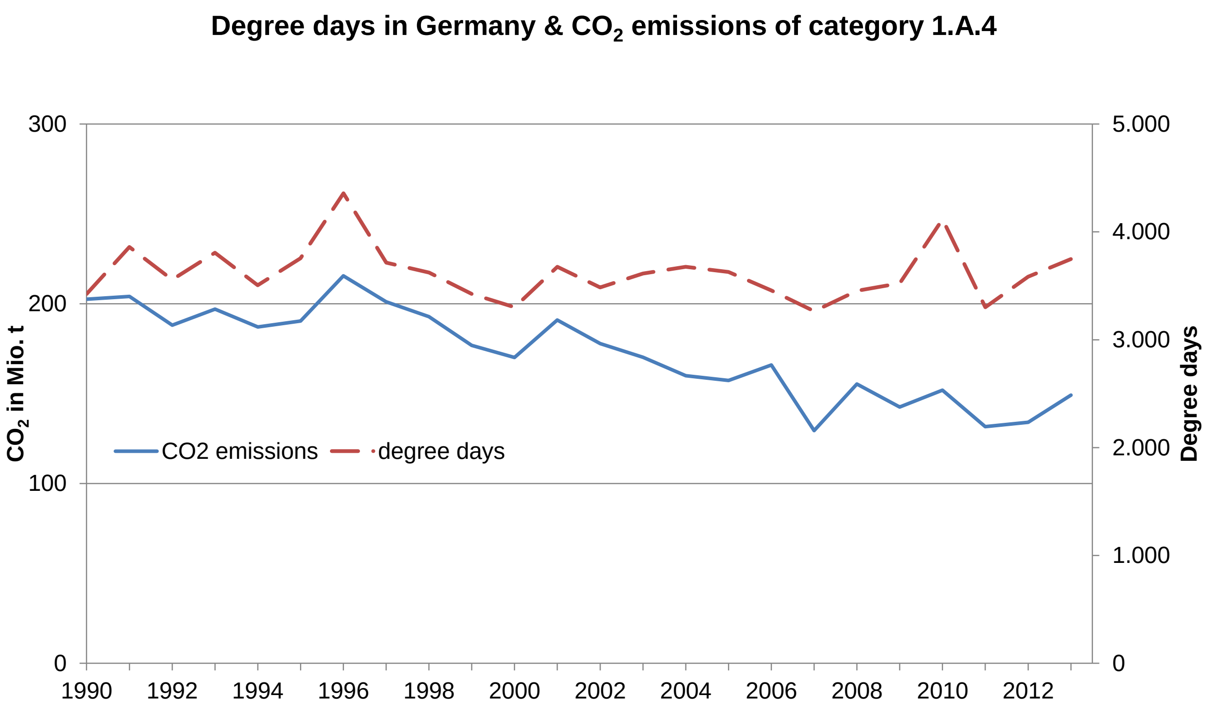

Figure 37: Change in total emissions of 1.A.4, as a function of temperature

The main driver of CO_2 emissions in 1.A.4 is energy consumption for purposes of space heating. Consequently, fluctuations in consumption can plausibly be attributed to differences in periods of winter cold. The trend toward lower CO_2 emissions is a result of higher standards for new buildings, of successful energy-efficiency-oriented modernisations of existing buildings and of switching to fuels with low CO_2 emissions. CO_2 emissions from electrically driven heat pumps, which are being used more and more frequently in new buildings, are not reported here.

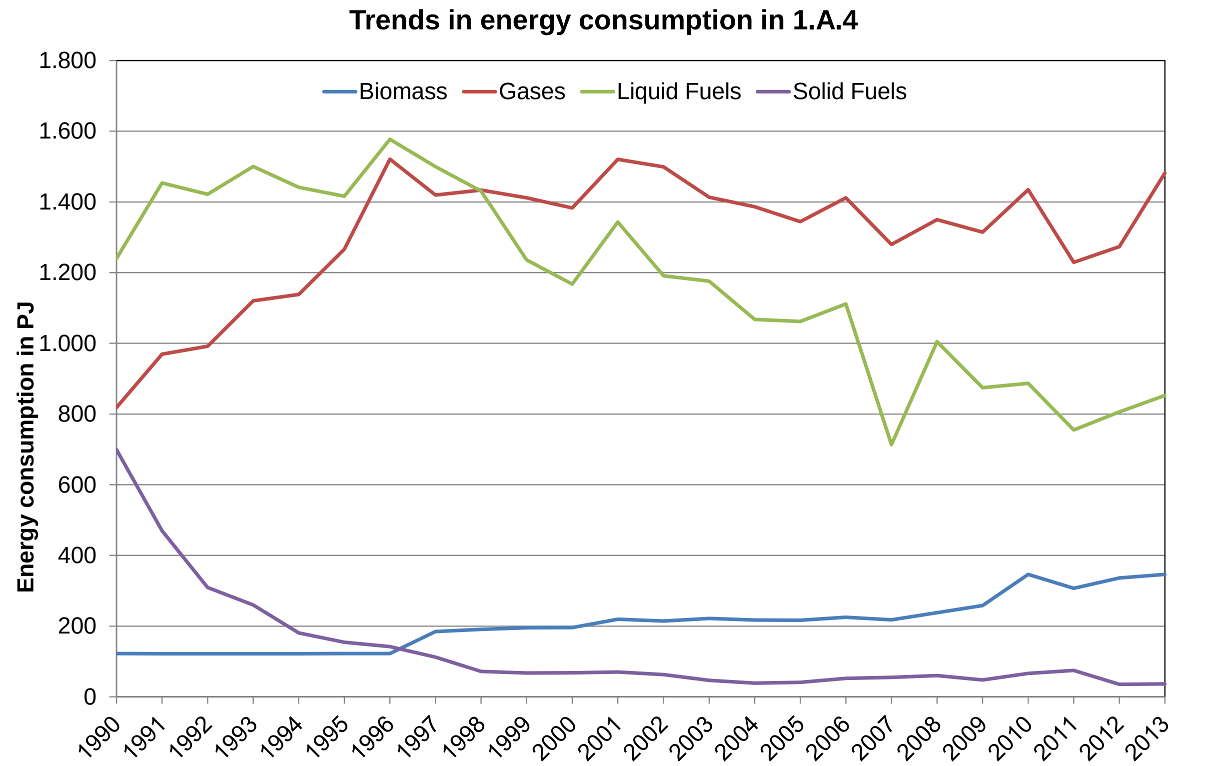

Figure 38: Trends in energy consumption in 1.A.4, for 4 fuel categories

Shifting from liquid fuels (almost exclusively heating oil) and solid fuels (mainly coal) to gaseous fuels (natural gas) and biomass has brought about considerable CO_2-emissions reductions. In 2006 and 2007, a special phenomenon occurred whereby energy consumption was first above-average and then below-average, respectively, as a result of an increase in the value-added-tax (VAT) rate from 16 % to 19 %. Very high heating-oil sales in 2006 increased CO_2 emissions figures, since emissions data relative to heating oil are determined on the basis of sales, rather than consumption. "The sharp decrease in energy consumption in 2011, especially in the market for heating energy, is due to the comparatively mild weather experienced in the winter heating period and to considerable increases in energy prices and costs. By contrast, relatively cold weather – both in the first half of 2012 and in 2013 – led to an increase in consumption of natural gas and heating oil for heating purposes" (source: Arbeitsgemeinschaft Energiebilanzen (Working Group on Energy Balances (AGEB)), Energieverbrauch in Deutschland ("energy consumption in Germany"), data for the 1st through 4th quarters of 2013).

The group of combustion systems in the Residential and Commercial/Institutional sectors is very diverse with regard to installation design and size. It covers a spectrum that includes individual room furnaces for solid fuels with a rated thermal output of approximately 4 kW (e.g. fireplaces, ovens), oil and gas furnaces used to generate room heat and hot water (e.g. central heating boilers), hand-fed and automatically fed wood-burning furnaces in the commercial sector and commercial/institutional users' licensable combustion systems with a rated thermal output of several megawatts, to name but a few examples. In total in 2005, more than 36.5 million combustion systems were installed (i.e. were in place) in Germany in the Residential and Commercial and Institutional sectors (STRUSCHKA, 2008: p. 12). Gas-fired combustion systems accounted for a majority of these systems, or some 14.5 million, while combustion systems using solid fuels accounted for some 14.4 million systems and oil-fired furnaces accounted for some 7.9 million systems. The great majority of these systems (about 95 %) are in place in private households (STRUSCHKA, 2008).

Of the wood fuels used in households and in commerce and trade, large quantities are purchased privately or obtained from system owners' own forest parcels. For this reason, in the Energy Balance, the relevant data from the Federal Statistical Office are supplemented with data from a survey of firewood consumption in private households. No official data are available on use of firewood in the categories commercial and institutional [commerce, trade and services]. As a result, data are taken from a pertinent study from the year 2000 (UBA 2000a). The consumption-level figures determined in that study have been adopted for subsequent years since then. A research project entitled "Development of methods for determination of consumption of biogenic solid fuels in the commercial and institutional sector" ("Methodenentwicklung zur Ermittlung des Verbrauchs biogener Festbrennstoffe im GHD-Sektor") was carried out to determine activity data on use of firewood in the commercial and institutional sector more precisely. Since the project yielded sample results for individual areas, a complete data set on the sector's firewood use – a data set that would support an update – is still lacking. The initial aim of the project was to develop a method that would lead to a general approach. A plan for a follow-on project that would be based on the experience gained to date, and that would complete the findings for other sectors as well, proved impossible to implement, due to a lack of suitable research contractors. The Energy Balance fuel category "Waste and other biomass" is specified in greater detail in the Satellite Balance. The information in that Balance indicates that only firewood is used in the residential sector, while only gas from wastewater treatment / biogas are used in the sector "Commercial, institutional (commerce/trade/services) and other consumers".

3.2.11.2 Methodological issues (1.A.4, stationary)

Activity data

The activity data in category 1.A.4 are based on the Energy Balances for the Federal Republic of Germany, as prepared by the Working Group on Energy Balances (AGEB). For years prior to 1995 separate Energy Balances are used for the a) old German Länder and b) new German Länder. For years as of 1995, lines 66 (residential) and 67 (commercial and institutional and other consumers) are the standard.

Since the data in Energy Balance line 67 – commercial and institutional and other consumers – also include military consumption, such military consumption must be deducted from the relevant positions in line 67 (cf. Chapter 3.2.13.2 with regard to stationary and mobile sources in the military sector).

For energy inputs in *Agricultural combustion systems (1.A.4.ci)*, which are also included in line 67 of the Energy Balance, relevant data are available, in an existing study (UBA, 2000a), for 1995. That study provides an estimate of agricultural combustion systems' share of total energy inputs in line 67. That share is assumed to have remained constant since then.

Emission factors

A detailed description of the relevant procedures, and a list of the CO_2 emission factors used, is presented in the Annex, Chapter 18.7.

The basic data for the emission factors used for N_2O und CH_4, for stationary combustion systems, is provided by the research report "Efficient provision of current emissions data for purposes of air quality control" ("Effiziente Bereitstellung aktueller Emissionsdaten für die Luftreinhaltung"; STRUSCHKA 2008). Within the context of that project, device-related and category-specific emission factors for combustion systems in the residential and commercial/institutional sectors were calculated, with a high level of detail, for all important emissions components for the reference year 2005.

Determination of emission factors is based on a category-specific "bottom-up" approach that, in addition, to differentiating (sub-) categories and fuels, also differentiates system technologies in detail. In the process, several system-specific emission factors are aggregated in order to obtain mean emission factors for all systems within the categories in question. Use of system-specific / category-specific emission factors ensures that all significant combustion-related characteristics of typical systems for the various categories are taken into account. The procedure is in keeping with the Tier 2/3 method described in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006).

The emission factors are structured in accordance with the relevant fuels involved in final energy consumption in Germany:

- Fuel oil EL
- Natural gas,
- Lignite (briquettes from the Rhine (Rheinisch) and Lusatian (Lausitz) coal fields; imported briquettes),
- Hard coal (coke, briquettes, anthracite) and
- Wood (unprocessed wood, wood pellets, residual wood).

In addition, emission factors for combustion systems are determined in accordance with device design, age level, output category and typical mode of operation. The emissions behaviour of the combustion systems in question was determined via a comprehensive review of the literature, in an approach that distinguished between results from test-bench studies and field measurements. Transfer factors were used to take account of the fact that emissions in a test-bench environment tend to be lower than those of corresponding installed systems.

The description of the structure for installed combustion systems was prepared using statistics from the chimney-sweeping trade, as well as with the help of surveys conducted by the researchers themselves in selected chimney-sweep districts of Baden-Wuerttemberg, North-Rhine Westphalia and Saxony. Those data were used to estimate the energy inputs for various system types, to make it possible to determine sectoral emission factors weighted by energy inputs. Table 48 shows the sectoral emission factors determined.

Table 48: Sectoral emission factors for combustion systems in the residential and commercial/institutional sectors for reference year 2005

	CH_4	N_2O
1.A.4.b i – Residential	[kg/TJ]	
Hard coal	129	11
Briquettes	368	9.7
Hard-coal coke	13	0.82
Lignite briquettes	55	5.2
Unprocessed wood	100	1.5
Heating oil EL	0.046	0.55
Natural gas	2.3	0.25
1.A.4.a i & c i – Commercial and Institutional		
Hard coal	100	10
Briquettes	-	-
Hard-coal coke	-	-
Lignite briquettes	-	-
Wood fuels	56	1.1
Heating oil EL	0.026	0.56
Natural gas	0.16	0.33

The emission factors for 2005 were used, without change, for subsequent years.

3.2.11.3 Uncertainties and time-series consistency (1.A.4, stationary)

Annex 2, Chapter 13.6 in the NIR 2007 describes the method used to determine the uncertainties for the **activity data**.

A complex procedure is required to calculate reliable emission factors in the installation sector. Apart from emission figures, it is also necessary to obtain other information; for example, one must make allowance for the relevant mode of operation (loads), installation structure and device-specific final energy consumption. In data surveys during the aforementioned research and development project, this approach was for the most part followed; nevertheless, given the sheer number of facilities concerned and the wide range of combustion systems and fuels used, the data must be assumed to have a fairly large "basic uncertainty".

For some installation types, moreover, only inadequate data or no data at all were available on emissions behaviour in connection with certain fuels. It is important to remember that the law does not require the greenhouse-gas emissions of combustion systems of residential and commercial/institutional users to be measured. When calculating the emission factors, therefore, in most cases (with the exception of CO_2, which is largely independent from furnace design) the researchers only had recourse to a few results from individual measurements on selected installations. Gaps in the data were closed via adoption of emission factors of comparable combustion systems.

The uncertainties listed for the emission factors for CH_4 and N_2O, for stationary combustion systems, were determined via expert estimation pursuant to IPCC-GPG (2000: Chapter 6). That assessment, which is based on the emissions data obtained for the aforementioned research project, was carried out in the framework of that project by experts of the University of Stuttgart's Institute of Process Engineering and Power Facility Technology (Institut für Verfahrenstechnik und Dampfkesselwesen). Uncertainties were estimated separately for all combustion technologies and fuels. The following sources of error entered into the estimates for N_2O and CH_4 :

- Measuring errors in determination of pollutant concentrations;
- Uncertainties in estimating transfer factors (systematic differences between test-bench and field measurements);
- Uncertainties resulting from having too little emissions data;
- Uncertainties resulting from use of different measuring procedures;
- Uncertainties in the installation data used (overall group structure in terms of type, age and performance and fuel consumption)

In gas-fired systems, another error occurs in determination of start-up/shutdown emissions. During start-up/shutdown procedures, some partly unburned CH_4 is emitted from natural gas. Those emissions, which occur upstream and downstream from the actual combustion process, cf. Chapter 3.3.2.2 (natural gas), are a significant reason why CH_4 emission factors for gas-combustion systems are subject to high levels of uncertainties.

As to the distribution of uncertainties, a log-normal distribution is assumed for N_2O emission factors. In all likelihood, the deviations are considerably more pronounced in the vicinity of larger values than they are in the vicinity of smaller values. The emission factors for CH_4 and N_2O were determined for the year 2005, in the framework of the aforementioned research project, and are assumed to have remained constant since then.

3.2.11.4 Category-specific QA/QC and verification (1.A.4, stationary)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

Information on quality assurance for **activity data** is provided in Chapter 3.2.6.4. For further information on quality assurance, cf. Chapter 18.4.1.

For the purposes of quality assurance for data relative to *stationary combustion systems*, in the context of the aforementioned research and development project, all the input data used from literature and from the research company's own investigations were reviewed for validity. As a general principle, in description of the emissions behaviour of combustion systems, emissions data were included in subsequent calculations only if the relevant literature sources contained complete, undisputed data on the fuel used, the design of the furnace, and the furnace's operating mode during measurements. All resources of significance for inventory preparation were substantiated by the research company.

In the framework of a quality review carried out by Federal Environment Agency experts, the country-specific emission factors for CH_4 and N_2O, determined in accordance with the Tier 2 standard, were compared with the IPCC Tier 2 default factors in the IPCC Guidelines for emissions inventories (IPCC 2006). For most fuels, the values agreed well (discrepancies within one order of magnitude), although the default values for CH_4 tended to be higher than the country-specific values.

In the framework of quality assurance, calculation with the Tier 1 default values was carried out, in addition to emissions determination pursuant to Tier 2/3, for the residential and commercial/institutional sectors for the year 2005. The results are shown in Table 49.

Table 49: Emissions calculation with country-specific Tier 2/3 emission factors and with the Tier 1 default emission factors pursuant to (IPCC 2006)

Emission factors	CH_4 [t]				N_2O [t]			
	Residential		Commercial and institutional		Residential		Commercial and institutional	
	Tier 1 default	Struschka 2008	Tier 1 default	Struschka 2008	Tier 1 default	Struschka 2008	Tier 1 default	Struschka 2008
Heating oil EL	6,590	30	2,489	6.5	395	357	149	139
Fuel gases	5,290	2,459	2,496	77	106	266	50	163
Coal fuels	13,452	4,568	6	58	67	340	1	5.6
Wood	60,194	20,001	5,749	1,081	803	284	77	6.2
Total	**85,526**	**27,058**	**10,740**	**1,223**	**1,371**	**1,247**	**279**	**313.8**

The emissions for the commercial/institutional ("small consumers") sector include the emissions of the areas of agriculture, forestry and fisheries.

For N_2O, the emissions-calculation results obtained with both methods showed good agreement. Larger discrepancies were seen in determination of CH_4 emissions. Presumably, this is due to the fact that methane emissions of combustion systems depend strongly on the combustion technology used. Differences in installation structures (i.e. in sector composition), from country to country, thus manifest themselves much more strongly in total emissions (as determined) than in nitrous-oxide emissions. The default emission factor for heating oil, in particular, is very high. The technology-specific emission factor given in IPCC 2006 for boilers shows considerably better agreement with the pertinent country-specific factor for Germany.

No data sources are known that would support a comparison with the data reported here for mobile sources in the residential, agricultural and fisheries sectors. In addition, the country-specific IEF were compared with those of other countries. Due to the heterogeneous composition of the sub-categories involved, however, that comparison is largely inconclusive – especially with regard to methane and nitrous oxide.

3.2.11.5 Category-specific recalculations (1.A.4, stationary)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

3.2.11.6 Category-specific planned improvements (1.A.4, stationary)

With regard to reporting on *stationary combustion systems*, review is currently being carried out to determine whether the applicable percentage for wood use can be determined via other scientific studies.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

3.2.12 Other: Residential, commercial/institutional, agriculture, forestry and fisheries (1.A.4 Mobile, recently separated out)

3.2.12.1 Category description (1.A.4, Mobile)

The stationary and mobile sources categories in 1.A.4 are placed in the relevant main categories together (for an overview, cf. Chapter 3.2.11.1). The category 1.A.4 *Other* is a key category for CO_2 emissions, in terms of both emissions level and trend, in all of its sub - categories.

Category 1.A.4 – mobile comprises various mobile sources in sub-categories 1.A.4.a ii – *Commercial and Institutional*, 1.A.4.b ii – *Residential*, 1.A.4.c ii – *Agriculture and forestry* and 1.A.4.c iii – *Fishing*.

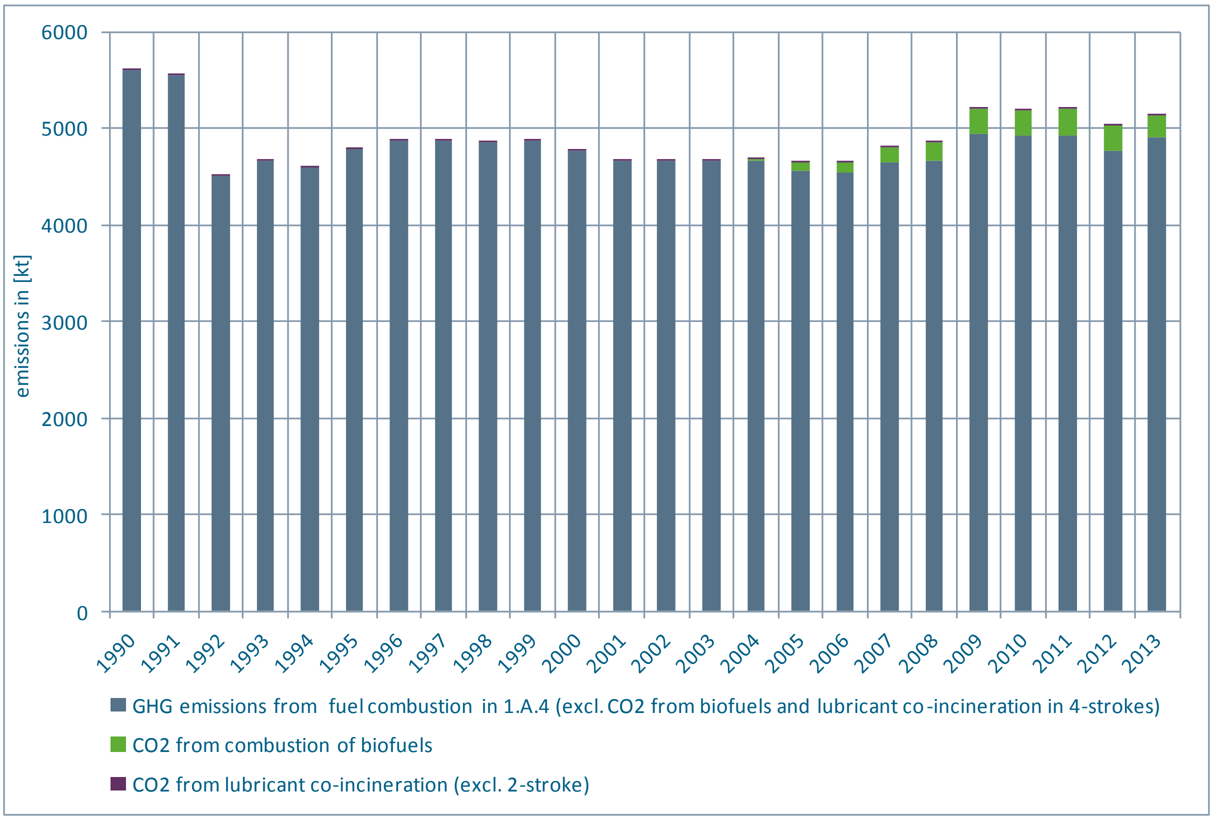

Figure 39: Development of GHG emissions from mobile sources in CRF 1.A.4., including commercial/institutional, residential, agriculture and forestry, and fishing, 1990 – 2013

3.2.12.2 Methodological issues (1.A.4, mobile)

Activity data

The **activity data** in category 1.A.4 are based, as described for the case of stationary combustion, on the National Energy Balances (NEBs), as prepared by the Working Group on Energy Balances (AGEB, 2014).

The quantities of gasoline fuels listed in NEB line 66 are all allocated to *Mobile sources in the residential sector* (sub-category *1.A.4.b ii*).

NEB line 67 – Commercial and Institutional also includes fuel consumption areas of the military sector that are that are separately recorded in (BAFA, 2014) statistics; those areas can thus be deducted here (cf. Chapter 3.2.14 regarding mobile sources in the military sector). The additional breakdown into mobile sources in *agriculture (1.A.4.c ii (i) and forestry (1.A.4.c ii (ii), construction vehicles and machinery (1.A.2.g vii),* and mobile sources in *1.A.4.b ii* (primarily forklifts), is carried out on the basis of an annual distribution key created in TREMOD-MM (IFEU, 2014b).

The activity data for the coastal and high-seas fisheries included under *1.A.4.c (iii) – Fishing* are obtained via (BSH, 2015), as described under 1.A.3.d. Inter alia, they are prepared on the basis of AIS data (data of the IMO's Automatic Identification System) and of data on fleet development and compositions pursuant to (EC, 2014).

In general, the pertinent quantities of co-combusted lubricants are derived, pursuant to (VSI, 2014), from the relevant annual fuel quantities. For two-stroke gasoline engines (in the residential and forestry sectors), those quantities are obtained as a two-percent addition to the quantities of gasoline used for refueling (cf. also Chapter 19.1.4).

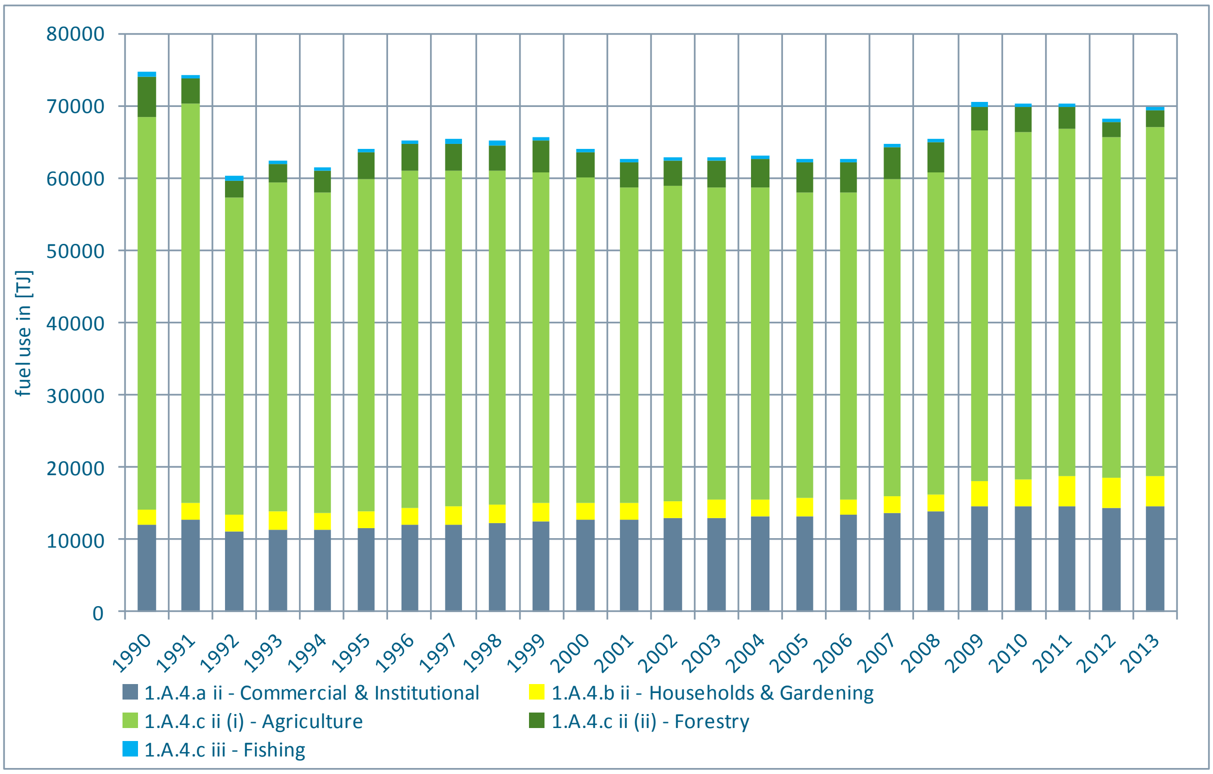

Figure 40: Development of fuel consumption within the various sub-categories since 1990

Emission factors

With regard to the CO_2 emission factors used, we refer to Chapter 18.7. Further information regarding co-combustion of lubricants in two-stroke engines is provided in Chapter 19.1.4.

For methane and nitrous oxide, country-specific values pursuant to (IFEU, 2014b) and (BSH, 2015) are used. With regard to releases of these two greenhouse gases from co-combustion of lubricants, it is assumed that such emissions are already taken into account in the pertinent emission factors for the fuels used and thus are to be reported as IE *(included elsewhere)*.

Table 50: EF(CH_4) and EF(N_2O) 2013, in [kg/TJ]; in parentheses: default values pursuant to (IPCC, 2006)

	CH_4	N_2O	Origin
1.A.4.a ii – Mobile sources in the Commercial and Institutional sector			
Diesel oil	1.84 (4.15)	2.99 (28.60)	pursuant to TREMOD-MM (IFEU, 2014b)
Biodiesel	1.84 (-)	2.99 (-)	equivalent to the EF for diesel oil
LPG	5.27 (-)	0.69 (-)	pursuant to TREMOD-MM (IFEU, 2014b)

	CH_4	N_2O	Origin
1.A.4.b ii – Mobile sources of the residential sector			
Gasoline (2-stroke)	246.16 (180)	0.42 (0.40)	pursuant to TREMOD-MM (IFEU, 2014b)
Bioethanol (2-stroke)	246.16 (-)	0.42 (-)	equivalent to the EF for gasoline (2-stroke engines)
Gasoline (4-stroke)	27.02 (120)	1.32 (2)	pursuant to TREMOD-MM (IFEU, 2014b)
Bioethanol (4-stroke)	27.02 (-)	1.32 (-)	equivalent to the EF for gasoline (4-stroke engines)
1.A.4.c ii (i) – Mobile sources of the agricultural sector			
Diesel oil	2.95 (4.15)	2.86 (28.6)	pursuant to TREMOD-MM (IFEU, 2014b)
Biodiesel	2.95 (-)	2.86 (-)	equivalent to the EF for diesel oil
1.A.4.c ii (ii) – Mobile sources of the forestry sector			
Diesel oil	0.94 (4.15)	3.10 (28.6)	pursuant to TREMOD-MM (IFEU, 2014b)
Biodiesel	0.94 ()	3.10 ()	equivalent to the EF for diesel oil
Gasoline (2-stroke)	204.49 (170)	0.46 (0.40)	pursuant to TREMOD-MM (IFEU, 2014b)
Bioethanol (2-stroke)	204.49 ()	0.46 ()	equivalent to the EF for gasoline (2-stroke engines)
1.A.4.c (iii) – Fishing (here: *high-seas fisheries)*			
Diesel oil	0.94 (-)	3.29 (-)	pursuant to (BSH, 2015)
Biodiesel	0.94 (-)	3.29 (-)	equivalent to the EF for diesel oil
Heavy fuel oil	0.80 (-)	3.33 (-)	pursuant to (BSH, 2015)
Overarching			
Co-combusted lubricants	IE	IE	included in the EF for the individual fuels

3.2.12.3 Uncertainties and time-series consistency (1.A.4, mobile)

The mathematical uncertainties to the specific energy inputs, which are dominated by the uncertainty of the distribution key developed in TREMOD MM (see above: Methodological Issues), are based on expert estimates. The same applies to the carbon dioxide emission factors used. Where the uncertainties of the methane emission factors on the other hand result from (IFEU & INFRAS, 2009), IPCC default values are applied for nitrous oxide.

3.2.12.4 Category-specific QA/QC and verification (1.A.4, mobile)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

Table 51: Overview of relevant comparisons

Comparison with...	Completed	Remark
alternative emissions inventories for Germany	no	no comparable data records
category-specific Tier-1 default EF pursuant to (IPCC, 2006; Tables 3.3.1 and 3.5.2 (1.A.4.c iii)): CO_2	yes	no comparable data records
category-specific Tier-1 default EF pursuant to (IPCC, 2006; Tables 3.3.1 and 3.5.3 (1.A.4.c iii)): CH_4, N_2O	yes	cf. Table 50
specific IEF of other countries	yes	cf. Table 53

Table 52: Comparison of the $EF(CO_2)$ used in the inventory with default values

	Inventory value	Default	*Lower bound*	*Upper bound*
Diesel oil	74,000	74,100	*72,600*	*74,800*
Gasoline				
2-stroke engines[1)]	73,095	69,300	*67,500*	*73,000*
4-stroke engines	73,091[2)]	69,300	*67,500*	*73,000*
LPG	65,413[2)]	63,100	*61,600*	*65,600*
Heavy fuel oil	80,007[2)]	77,400	*75,500*	*78,800*
Co-combusted lubricants[3)]	73,300	73,300	*71,900*	*75,200*
Biodiesel	70,800	70,800	*59,800*	*84,300*
Bioethanol				
2-stroke engines[1)]	71,641	70,800	*59,800*	*84,300*
4-stroke engines	71,606	70,800	*59,800*	*84,300*

[1)] including two percent lubricants
[2)] value for 2013
[3)] CO_2 from co-combustion of lubricants (except for two-stroke engines) is reported under CRF 2.D.1

The following table provides a comparison with specific implied emission factors of other countries as well as with the relevant values resulting for the EU(28). It should be noted that the comparison is hampered by the fact that the factors involved represent an extremely heterogeneous group of categories.

Table 53: International comparison of reported IEF (all figures in [kg/TJ])

	Fossil liquid fuels		
	CO_2	CH_4	N_2O
Germany	72,897	8.88	2.50
Denmark	75,074	8.03	2.51
France	73,572	8.82	1.65
Netherlands	73,113	4.16	0.53
Norway	73,411	6.65	5.28
Switzerland	73,698	1.63	0.70
UK	70,129	7.58	9.15
EU (28)	72,623	4.95	2.94

Germany: current IEF for 2013; all other countries: IEF for 2012, pursuant to 2014 CRF Tables

3.2.12.5 Category-specific recalculations (1.A.4, mobile)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

3.2.12.6 Category-specific planned improvements (1.A.4, mobile)

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

3.2.13 *Other sectors (1.A.5.a stationary)*

Category 1.A.5 comprises the combustion-related emissions of the military sector. It is divided into the categories 1.A.5.a *"Stationary"* and 1.A.5.b *"Mobile"*.

3.2.13.1 Category description (1.A.4 Stationary)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T	**1.A.5 Other: Include Military fuel use under this category**	**All fuels**	**CO_2**	**11,791.9**	**(0.97%)**	**1,039.2**	**(0.11%)**	**-91.2%**
-/-	1.A.5 Other: Include Military fuel use under this category	All fuels	CH_4	279.4	(0.02%)	1.4	(0.00%)	-99.5%
-/-	1.A.5 Other: Include Military fuel use under this category	All fuels	N_2O	61.3	(0.01%)	3.6	(0.00%)	-94.1%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS, Tier 1	NS	CS/D
CH_4	CS, Tier 1, Tier 3	NS/M	CS/D/M
N_2O	CS, Tier 1, Tier 3	NS/M	CS/D/M

The stationary and mobile sources categories in 1.A.5 are placed in the relevant main categories together. The category *Other* is a key category for CO2 emissions in terms of both emissions level and trend.

The following figure shows the emissions trend since 1990.

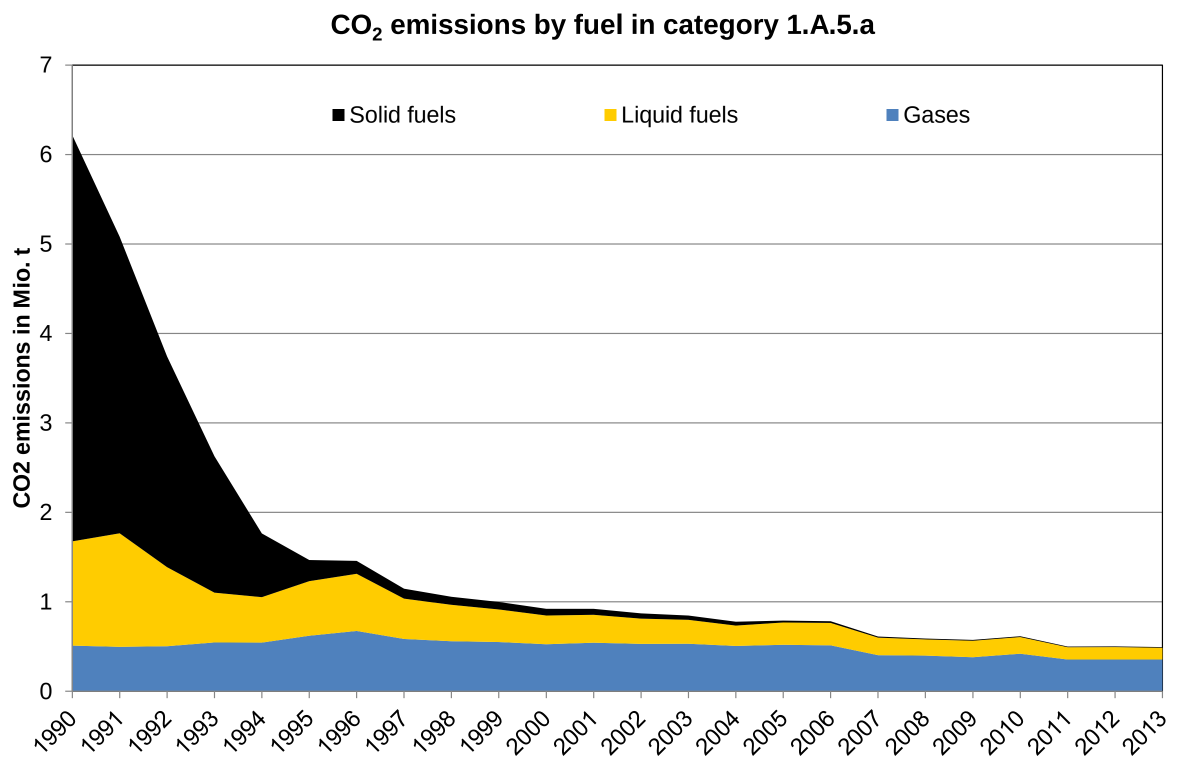

Figure 41: Development of CO_2 emissions in category 1.A.5.a

The especially large emissions reduction is the result of closure of many military agency locations, as well as of considerable shifting from use of solid fuels to use of gaseous and liquid fuels.

3.2.13.2 Methodological issues (1.A.5.a, stationary)

Activity data

The National Energy Balance (NEB) (AGEB) provides the basis for the activity data used. Since the NEB does not provide separate listings of military agencies' final energy consumption as of 1995 – and includes that consumption only in line 67, under "commercial, institutional and other consumers" – additional sources of energy statistics had to be found for this category.

For reporting, use is made of data of the Bundesamt für Infrastruktur, Umweltschutz und Dienstleistungen der Bundeswehr (BAIUDBw (Federal office for infrastructure, environmental protection and services of the German Armed Forces"), 2014), which reports the "Energy input for heat production in the German Federal Armed Forces", by fuels and (in the present case) for 2000-2013, to the Federal Environment Agency. Those figures are deducted from the figures in Energy Balance line 67 (commercial, institutional) and are reported in 1.A.5, rather than in 1.A.4. Since the 2008 report year, use of wood in category 1.A.5.a is also reported.

Emission factors

A detailed description of the relevant procedures, and a list of the CO_2 emission factors used, is presented in the Annex, Chapter 18.7.

The database for the emission factors used for all other pollutants consists of the results of a research project carried out by the University of Stuttgart, under commission to the Federal Environment Agency (STRUSCHKA, 2008). Within that project, device-related and category-specific emission factors for combustion systems in military agencies were calculated, with a high level of detail, for all important emissions components for the reference year 2005. The method used to determine the factors conforms to the procedure described for category 1.A.4. Table 54 shows the sectoral emission factors used.

Table 54: Sectoral emission factors for the military sector

	CH_4	N_2O
	[kg/TJ]	
Stationary combustion in military agency locations		
Hard coal	2.0	4.8
Lignite briquettes	242	0.37
Heating oil EL	0.017	0.56
Natural gas	0.042	0.29

3.2.13.3 Uncertainties and time-series consistency (1.A.5.a, stationary)

Information regarding the uncertainties for the emission factors is provided in the description for category 1.A.4. Annex 2 Chapter 13.6 in the NIR 2007 describes how the uncertainties for the activity data were determined.

3.2.13.4 Category-specific QA/QC and verification (1.A.5.a, stationary)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

Since no other sources of data for Germany are known, it is currently not possible to verify the emissions reported here via comparison.

3.2.13.5 Category-specific recalculations (1.A.5.a, stationary)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

3.2.13.6 Category-specific planned improvements (1.A.5.a, stationary)

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

3.2.14 Other (1.A.5.b Mobile)

3.2.14.1 Category description (1.A.5.b)

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1*, CS	NS/M**	CS, D*
CH_4	CS, Tier 1, Tier 3	NS/M**	CS (M)
N_2O	CS, Tier 1, Tier 3	NS/M**	CS (M)

* biodiesel, avgas and co-combusted lubricants

** Military aviation: pursuant to (IFEU & ÖKOINSTITUT, 2014), military. maritime transport: pursuant to (BSH, 2015)

The stationary and mobile sources categories in 1.A.5 are placed in the relevant main categories together (for an overview, cf. Chapter 3.2.13.1.). The category *1.A.5 – Other* is a key category for CO2 emissions in terms of both emissions level and trend.

The following figure shows the development of greenhouse-gas emissions since 1990, which development parallels that for fuel inputs in this category.

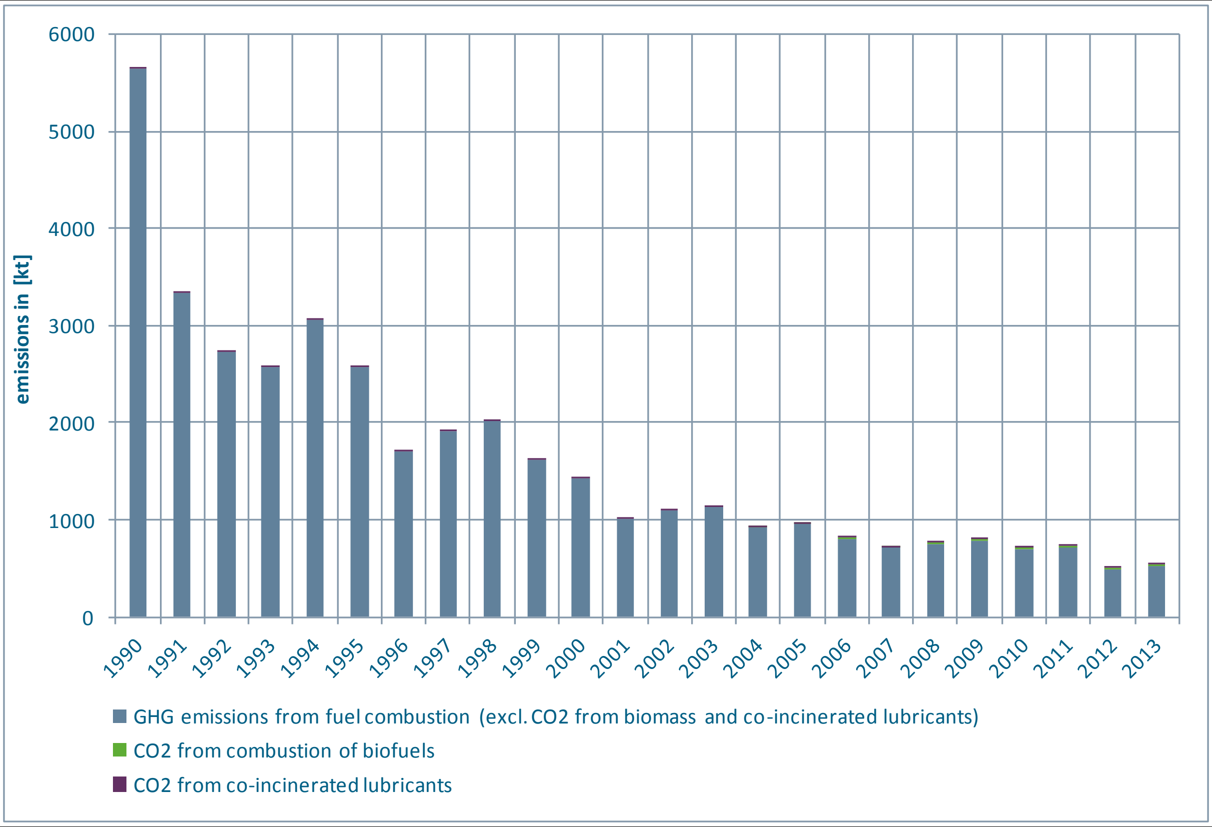

Figure 42: Development of GHG emissions from military mobile sources represented in CRF 1.A.5.b., 1990 – 2013

3.2.14.2 Methodological issues (1.A.5.b Mobile)

Activity data

The activity data used are based on the National Energy Balance (NEB) (AGEB), which provides fuel-input data for military air and ground transports (diesel oil and gasoline, including biogenic admixtures, kerosene, avgas) only for the period until 1993. Beginning in 1994, such data are obtained from the *Official Mineral Oil Statistics for the Federal Republic of Germany*, which are published by (BAFA, 2014). The consumption figures in that source, which are given in units of 1000 t, are converted into terajoules on the basis of the pertinent listed net calorific values. On the other hand, the fuel inputs in the naval sector are only a sub-quantity of the quantities listed in NEB line 6 – International marine bunkers. They are thus calculated separately in (BSH, 2015), as described in Chapter 3.2.10.4.

In addition, the quantities of co-combusted lubricants are derived via co-combustion rates, pursuant to (VSI, 2014), from the total quantities of the fuels used in sub-categories 1.A.5.b i through iii (cf. also Chapter 19.1.4).

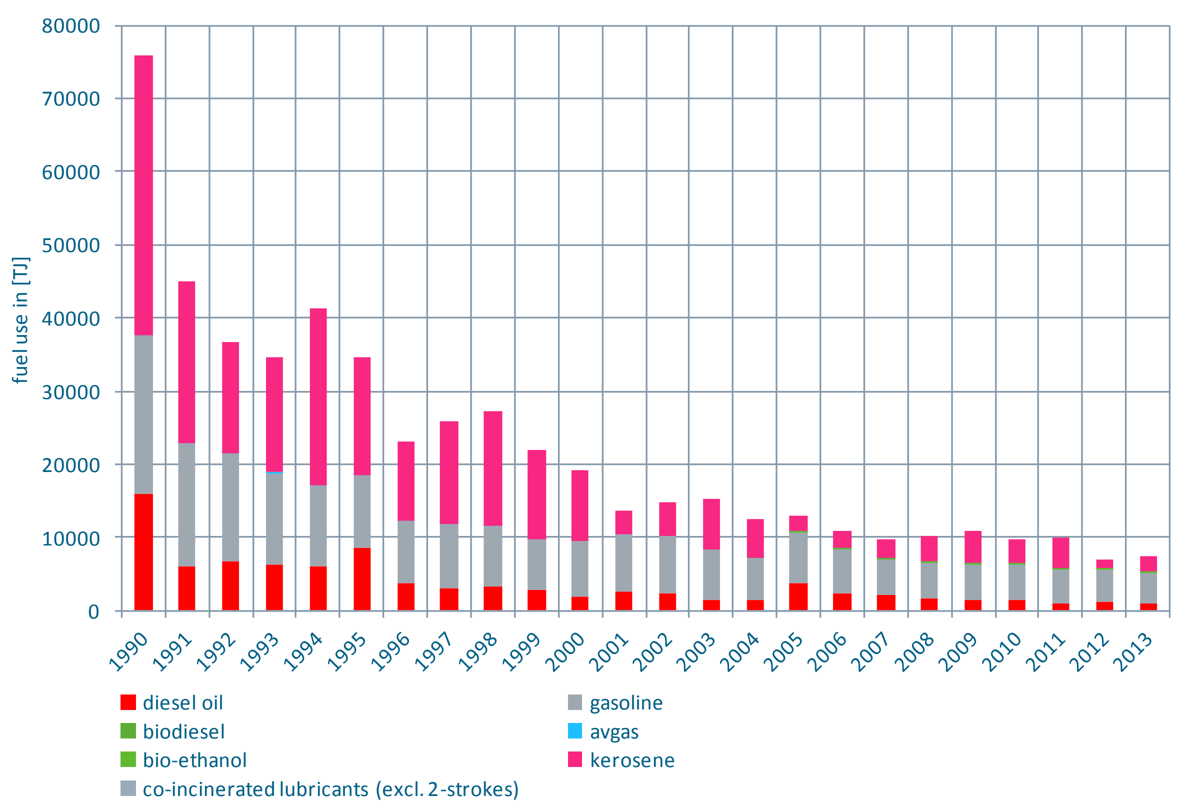

Figure 43: Development of fuel consumption since 1990

Emission factors

With regard to the CO_2 emission factors used, we refer to Chapter 18.7. Further information regarding co-combustion of lubricants is provided in Chapter 19.1.4.

For methane and nitrous oxide, country-specific values are also used for ground transports and for use of avgas. For jet kerosene, IPCC default figures are used, in light of the fact that the aircraft used by the sector differ strongly from those used in civil aviation. The emission factors used for the naval sector are taken from (BSH, 2015). With regard to releases of these two greenhouse gases from co-combustion of lubricants, it is assumed that such emissions are already taken into account in the pertinent emission factors for the fuels used and thus are to be reported as IE *(included elsewhere)*.

Table 55: EF(CH_4) und EF(N_2O) 2013, in [kg/TJ]; in parentheses: Default values pursuant to (IPCC, 2006)

	CH_4	N_2O	Origin
1.A.5.b i – ground vehicles			
Diesel oil	2.97 (-)	0.81 (-)	IEF pursuant to SNF in 1.A.3.b
Biodiesel			equivalent to the EF for diesel oil
Gasoline	7.04 (-)	0.72 (-)	IEF pursuant to 1.A.3.b
Bioethanol			equivalent to the EF for gasoline
1.A.5.b ii – military aircraft			
Kerosene	0.50 (0.50)	2.00 (2.00)	Tier 1 default value pursuant to (IPCC, 2006)
Avgas[3)]	8.21 (-)	2.33 (-)	cf. 1.A.3.a
1.A.5.b iii – naval			
Diesel oil	0.81 (7.00)	3.29 (2.00)	pursuant to (BSH, 2015)
Biodiesel			equivalent to the EF for diesel oil
Heavy fuel oil	NO	NO	
1.A.5.b – overarching			
Co-combusted lubricants	IE	IE	included in the EF for fuels

3.2.14.3 Uncertainties and time-series consistency (1.A.5.b, mobile)

Within sub-sectors 1.A.5.b i and ii, default uncertainties pursuant to IPCC are used. In a departure from that procedure, specific uncertainties for activity data and emission factors for military maritime transports were derived in (BSH, 2015).

3.2.14.4 Category-specific QA/QC and verification (1.A.5.b, mobile)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

Table 56: Overview of relevant comparisons

Comparison with...	Completed	Remark
alternative emissions inventories for Germany	no	no comparable data records
category-specific Tier 1 default EF pursuant to (IPCC, 2006): CO_2	(yes)	1.A.5.b i: No specific Tier 1 defaults 1.A.5.b ii & iii: cf. Table 57
Tier 1 default EF pursuant to (IPCC, 2006; Table 2.4): CO_2	yes	1.A.5.b i: cf. Table 57
category-specific Tier 1 default EF pursuant to (IPCC, 2006): CH_4, N_2O	(yes)	1.A.5.b i: No specific Tier 1 defaults 1.A.5.b ii & iii: cf. Table 54
Tier 1 default EF pursuant to (IPCC, 2006; Table 2.4): CH_4, N_2O	yes	1.A.5.b i: cf. Table 54
specific IEF of other countries	yes	cf. Table 53

Table 57: Comparison of the EF(CO_2) used in the inventory with default values

	Inventory value	Default	*Lower bound*	*Upper bound*
Diesel oil	74,000	74,100	*72,600*	*74,800*
Gasoline	73,091[1)]	69,300	*67,500*	*73,000*
Kerosene	73,256	71,500	*69,800*	*74,400*
Avgas	70,000	70,000	*67,500*	*73,000*
Co-combusted lubricants[2)]	73,300	73,300	*71,900*	*75,200*
Biodiesel	70,800	70,800	*59,800*	*84,300*
Bioethanol	71,607	70,800	*59,800*	*84,300*

[1)] value for 2013

[2)] CO_2 from co-combustion of lubricants is reported under CRF 2.D.1

The following table provides a comparison with specific implied emission factors of other countries as well as with the relevant values resulting for the EU(28).

Table 58: International comparison of reported IEF (all figures in [kg/TJ])

	Fossil liquid fuels		
	CO_2	CH_4	N_2O
Germany	73,252	4.50	1.20
Denmark	72,995	2.23	2.35
France	NO	NO	NO
Netherlands	73,770	7.28	4.35
Norway	73,284	3.24	4.21
Switzerland	73,212	3.50	2.33
UK	72,410	2.01	2.16
EU (28)	72,579	5.23	4.18

Germany: current IEF for 2013; all other countries: IEF for 2012, pursuant to 2014 CRF Tables

3.2.14.5 Category-specific recalculations (1.A.5.b Mobile)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

3.2.14.6 Category-specific planned improvements (1.A.5.b Mobile)

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

3.2.15 Military

Emissions from international deployments by the Federal Armed Forces, under a UN mandate, are not recorded as a separate activity for purposes of German emission inventories. Such recording will be again be a matter for discussion in the framework of the National Emissions Reporting System. For various reasons, the relevant required activity data are not provided.

This practice does not lead to any omissions in the inventories, since the fuel inputs associated with such deployments are included in national military consumption figures.

The basis for activity data for military fuels consists of the Official Mineral Oil Statistics for the Federal Republic of Germany (BAFA, 2014).

In the CSE, category 1.A.5 includes, under stationary sources, heat production of military agencies; under mobile sources, it includes military transports and aviation.

3.3 Fugitive emissions from fuels (1.B)

During all stages of fuel production and use, from extraction of fossil fuels to their final use, fuel components can escape or be released as fugitive emissions. While methane emissions are the most important emissions within the category areas of fugitive emissions from solid fuels and fugitive emissions from natural gas, fugitive emissions of oil and natural gas also include substantial amounts of NMVOC. In category 1.B, carbon dioxide plays only a minor role in connection with processing of solid fuels, processing of hydrogen sulfide and flaring. Category 1.B. is not a source for fluorinated gases.

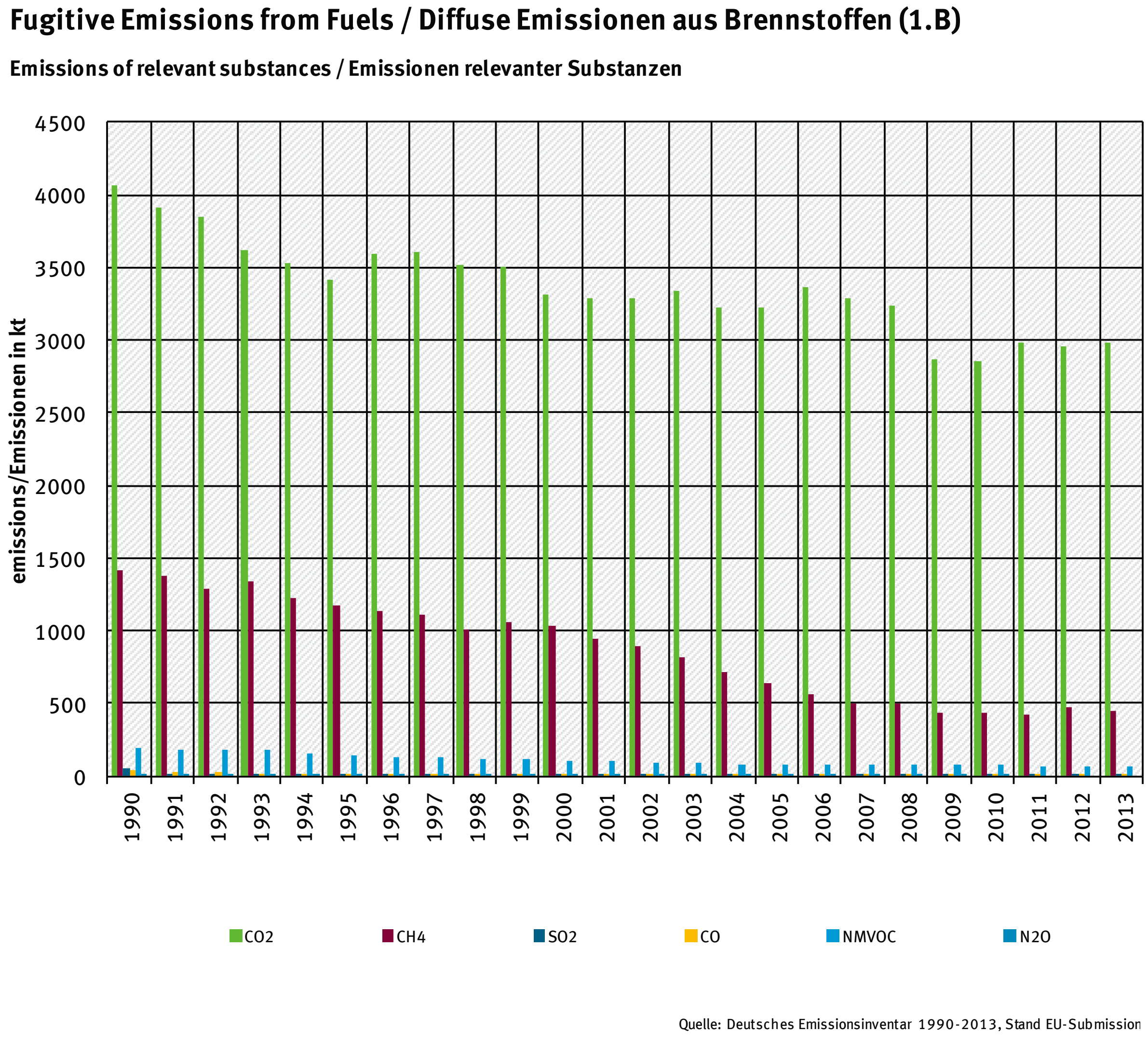

Abbildung 44: CRF 1.B - Emissions of relevant substances

3.3.1 *Solid fuels – coal mining and handling (1.B.1)*

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T/2	**1.B.1 Fugitive Emissions from Fuels**	**Solid Fuels**	**CH4**	**25.553,4**	**(2,10%)**	**3.580,2**	**(0,38%)**	**-86,0%**
-/-	1.B.1 Fugitive Emissions from Fuels	Solid Fuels	CO2	1.832,8	(0,15%)	707,0	(0,08%)	-61,4%

The category *coal mining and handling* is a key category for CH_4 emissions in terms of emissions level and trend and of Tier 2 analysis.

In mining, a distinction is made between surface mining, in which deposits are extracted from pits open to the surface, and underground mining, in which deposits are extracted from sites underground. All hard coal mining in Germany is underground mining, while (since 2003) all lignite mining is open-pit mining.

This category is subdivided as follows:

Category				Included emissions
1.B.1.a. Coal mining				
	i.	**Underground mining**		
			Mining activities	Total emissions from active hard-coal mines, consisting of emissions from a) mine ventilation and b) mine-gas extraction, less the quantity of mine gas recovered and utilised
			Follow-up mining activities	Emissions from processing, storage and transport of hard coal
			Decommissioned coal mines	Emissions from decommissioned hard-coal mines and emissions from flaring
	ii.	**Open-pit mining**		
			Mining activities	Emissions from active open-pit lignite mining. Here, the entire potential methane content of German lignite is used as the basis – this methane is assumed to be emitted, in its entirety, during mining. Any later emissions of methane, during further processing, are thus already taken into account. No pit-gas collection or use takes place in open-pit mining.
			Subsequent post-mining activities	No separate listing – the emissions are already included in "mining activities"
1.B.1.b. Solid fuel transformation – coal processing and charcoal production				Emissions from coal processing and charcoal production. This area takes account of specific emissions that occur in hard-coal processing. Methane emissions from lignite processing are already included in 1.B.1.a.ii "Mining activities". The assumed activity data cover the total for all processed products from hard coal and lignite.
1.B.1.c. Other				No emissions are currently being reported in this category.

Emissions and trend (1.B.1)

Table 59: Calculation of methane emissions from coal mining for 2013

			Activity data [Mt]	CH_4 emissions [kt]
1.B.1.a. Coal mining			(= 1.B.1.a.i + 1.B.1.a.ii) = 10.77 + 185.43 **=190.26**	(= 1.B.1.a.i + 1.B.1.a.ii) 136.85 + +2.01 **= 138.86**
	i.	**Underground mining**		= **mining and post-mining activities** = 131.79 + 4.36 + 0.70 **= 136.85**
		Mining activities Hard-coal extraction [1]	**7.57**	= AD * EF = 7.57 * 17.41 **= 131.79**
		Subsequent post-mining activities		**= 4.36**
		Decommissioned coal mines		Potential emissions, minus gas usage **= 0.70**
	ii.	**Open-pit mining**		= **mining activities** **= 2.01**
		Mining activities Lignite extraction [1]	**182.70**	= AD * EF = 182.70 * 0.011 **= 2.01**
		Subsequent post-mining activities		(included in 1.B.1.a.ii "mining activities") **IE**
1.B.1.b. Solid fuel transformation				**=0.40**
	Coal processing Total for processed products [2] [1]		**6.78**	$AD_{hard\text{-}coal\ prod.} * EF_{hard\text{-}coal\ prod.} + AD_{lignite\ prod.} * EF_{lignite\ prod.}$ = 8.1 * 0.049 + 6.97 * 0 **= 0.40**

1) Pursuant to STATISTIK DER KOHLENWIRTSCHAFT coal-sector-statistics association (n.y.)

2) Hard-coal coke, hard-coal briquettes, lignite coke, coal dust, dry coal, fluidised-bed coal, lignite briquettes, lignite granulate

3.3.1.1 Underground mining – hard coal

3.3.1.1.1 Category description (underground mining – hard coal)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 3	AS	CS
CO_2	M	AS	CS

Activity data

Table 60: Utilisable hard coal extracted

1990	1995	2000	2005	2010	2012	2013
70.2 million t	53.6 million t	33.6 million t	24.9 million t	12.9 million t	10.8 million t	7.6 million t

(STATISTIK DER KOHLENWIRTSCHAFT coal-sector-statistics association, n.y.).

Table 61: Number of active hard-coal mines

1990	1995	2000	2005	2010	2012	2013
27	19	12	9	5	4	3

(STATISTIK DER KOHLENWIRTSCHAFT coal-sector-statistics association, n.y.).

Emission factors

An implied emission factor (IEF) can be derived from the figures for total methane emissions and from the relevant activity data for hard-coal mining. This calculation takes mine-gas usage into account. The measurements cover only actually emitted quantities of methane.

For calculation of CH_4 emissions from hard-coal storage, the activity data for hard-coal production is used as a basis and then multiplied by the emission factor of 0.576 kg/t. That emission factor has been taken from a study of the Fraunhofer Institute for Systems and Innovation Research (FhG-ISI) (1993).

Table 62: Methane emission factors for the area of hard-coal extraction and storage, for the year 2013

Emission factors	**m^3 CH_4/t**	**kg/t**
CH_4 from extraction	40.88	27.39
CH_4 from extraction, less mine gas utilised	25.98	17.41
CH_4 from storage	0.87	0.58
CH_4 from mining (extraction and storage, less mine gas utilised)	26.85	17.99

No emission factor can be provided for decommissioned coal mines, since there are no pertinent activity data.

Emissions and trend

Table 63: Emissions in category 1.B.1.a.i – underground mining

Gas	**Total emissions**			**Trend**		**Remark**
	1990	**2012**	**2013**	**Since 1990**	**With respect to the previous year**	
Methane	975 kt	154 kt	134 kt	- 84 %	-13 %	The emissions have been decreasing as a result of decreases in utilisable extracted quantities and of increases in pit-gas utilisation since 2001.

3.3.1.1.2 Methods *(Underground mining – hard coal)*

Emissions from underground hard-coal mining are calculated pursuant to the Tier 3 method, in a procedure that meets requirements pertaining to mine-specific emissions determination. For safety reasons, gas compositions and air flows are measured continuously in all pit systems. The resulting data is used to determine levels of methane emissions. The Gesamtverband Steinkohle (GVSt) association of the German hard-coal-mining industry determines the total methane quantity by aggregating the relevant individual measurements. Expert review is carried out by the competent state supervisory authority (the mining authority – Bergamt).

3.3.1.1.3 Uncertainties and time-series consistency *(underground mining – hard coal)*

The uncertainties in the activity data result primarily from inaccuracies in weighing of extracted coal. Via surveys of experts carried out during the NaSE workshop of 11/2004, the relevant error has been quantified as <3 %.

Uncertainties in calculation of methane releases result from inaccuracies in measurements. As a result of the facts that underground measurements of methane concentrations are carried out primarily for safety reasons, and that their most precise measurement range does not fall within the range of common gas-release concentrations, the available measuring equipment can be expected to have a technical measurement inaccuracy of about 10 % [expert discussion on mine gas, Berlin, December 2009].

Methane releases from hard coal, during storage and transport, fluctuate considerably in keeping with storage duration and grain-size distribution. An uncertainty of 15 % is assumed [LANGE 1988 / BATZ 1995, along with information communicated personally at the NaSE workshop 11/2004].

The methane potential has been estimated on the basis of experts' knowledge. In this area, an uncertainty of 60 % has been assumed.

For the activity data, a consistent source is used throughout the entire time series.

3.3.1.1.4 Category-specific quality assurance/control and verification (underground mining – hard coal)

Due to a momentary lack of relevant staff within the Federal Environment Agency (UBA), it has not yet been possible to have quality control and quality assurance carried out by source-category experts - this will be made up leeway after return of the relevant person (generally with the next reporting). General and category specific quality control and quality assurance , according to the QSE-Handbook, have been carried out by the Single National Entity. Data were taken from previous years or determined on the basis of existing calculation routines.

For underground hard-coal mining, the 2006 IPCC Guidelines recommend emission factors on the order of 10 to 25 m³/t. Conversion of the German emission factors, using a conversion factor of 0.67 Gg/10^6 m³ (2006 IPCC Guidelines, Chapter 4: at 20° C, 1 atmosphere) yields the individual values listed in Table 62. When production, storage and deductable mine-gas use are combined in one emission factor, the resulting value per tonne of coal (marketable production) lies within the recommended range.

The emissions from decommissioned hard-coal mines, as determined by the Gesamtverband Steinkohle (GVSt) association of the German hard-coal-mining industry, have been verified via the research project "Potential for release and utilisation of mine gas" ("Potential zur Freisetzung und Verwertung von Grubengas") [DMT, 2014]. The relevant calculations were carried out for all regions with deposits in Germany.

The relevant figures for 2012, as reported in the 2014 Submission, have been compared with the corresponding figures of neighbouring countries.

Table 64: IEF for underground hard-coal mining: Germany as compared with neighbouring countries (NIR 2014)

	Hard coal extracted	Reported emissions	IEF
Germany	**10.8 million t**	**151.1 kt**	**14.0 kg/t**
Czech Republic	11.4 million t	100.1 kt	8.8 kg/t
UK	6.2 million t	65.4 kt	10.5 kg/t
Poland	71.3 million t	324.7 kt	4.6 kg/t
IPCC GL 2006			6.7 – 15.5 kg/t

3.3.1.2 Open-pit mining – lignite

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	AS	CS

3.3.1.2.1 Category description (open-pit mining – lignite)

Activity data

Table 65: Extraction of lignite

1990	1995	2000	2005	2010	2012	2013
356.5 million t	192.7 million t	167.7 million t	177.9 million t	169.4 million t	185.4 million t	182.7 million t

(STATISTIK DER KOHLENWIRTSCHAFT coal-sector-statistics association, n.y.).

Emission factors

In keeping with figures of the DEBRIV German lignite-industry association (Deutscher Braunkohlen-Industrie-Verein e.V; DEBRIV 2004), an average emission factor of 0.015 m³ CH_4/t (corresponds to 0.011 kg CH_4/t) is assumed for German lignite. This emission factor is based on a 1989 study of RWE Rheinbraun AG [DEBRIV, 2004] and has been substantiated by publications of the Öko-Institut e.V. Institute for Applied Ecology and of the DGMK [German Society for Petroleum and Coal Science and Technology; research report / Forschungsbericht 448-2, 1992].

No lignite storage takes place; usage is "mine-mouth", i.e. extracted coal is moved directly to processing and to power stations.

Table 66: Emissions in category 1.B.1.a.ii – open-pit mining

Emission factors	m^3 CH_4/t	kg/t
CH_4 from extraction	0.016	0.011

Emissions and trend

Table 67: Emissions in category 1.B.1.a.ii – open-pit mining

Gas	Total emissions			Trend		Remark
	1990	2012	2013	Since 1990	With respect to the previous year	
Methane	3.9 kt	2.0 kt	2.0 kt	-49 %	- 1%	The emissions have been decreasing as a result of reductions in lignite production.

3.3.1.2.2 Methods (open-pit mining – lignite)

Emissions from open-pit lignite mining have been calculated, in keeping with the Tier 2 method, pursuant to the relevant equation in the IPCC Reference Manual (IPCC, 1996b).

3.3.1.2.3 Uncertainties and time-series consistency (open-pit mining – lignite)

The emission factor used for calculating methane emissions from lignite production is based on maximum methane content levels and thus represents the upper limit of possible methane emissions. It thus already includes possible emissions from transport and storage. Numerous studies have shown that a negative uncertainty of - 33 % must be assumed [DEBRIV / DGMK research report / Forschungsbericht 448-2, DGMK 1992].

For the emission factor and the activity data, a consistent source is used throughout the entire time series.

3.3.1.2.4 Category-specific quality assurance/control and verification (open-pit mining – lignite)

Due to a momentary lack of relevant staff within the Federal Environment Agency (UBA), it has not yet been possible to have quality control and quality assurance carried out by source-category experts - this will be made up leeway after return of the relevant person (generally with the next reporting). General and category specific quality control and quality assurance , according to the QSE-Handbook, have been carried out by the Single National Entity. Data were taken from previous years or determined on the basis of existing calculation routines.

In the framework of verification for the current report, various data sources for activity data in coal mining, and the relevant EF used, were compared with the corresponding sources and EF of other countries (cf. Table 68). A by-country comparison of specific emission factors for open-pit mining shows a broad range, with Germany in the lower part of the range, in a position comparable to that of Poland. The 2011 NIR (p.103) noted that the Czech Republic uses the average IPCC default factor, in keeping with the fact that the coal mined in that country, in comparison to the coal mined in Poland and Germany, consists to a larger extent of sub-bituminous coal. The degree of coalification (rank) – and, thus, the methane content – of such coal is higher than that of the lignite found in Poland and Germany [sources: NaSE workshop 11/2004; personal communication of DEBRIV from 2005]. An assessment by VERICO [VERICO SCE 2014] reached the same conclusion.

Table 68: IEF for open-pit lignite mining: Germany as compared with neighbouring countries (NIR 2014)

	Extracted lignite	Reported emissions	IEF
Germany	**185.4 million t**	**2.0 kt**	**0.011 kg/t**
Poland	64.3 million t	0.8 kt	0.012 kg/t
Czech Republic	43.5 million t	33.5 kt	0.770 kg/t
IPCC GL 2006			0.2 – 1.3 kg/t

The IPCC emission factors have been derived from figures for American bituminous coal and thus, according to national experts, cannot be applied to German lignite, which did not exceed a temperature of 50°C during the coalification process. Significant methane releases occur only at temperatures above 80°C [DGMK Bericht 448-2, 1992].

3.3.1.3 Solid fuel transformation

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	AS	CS
CO_2	Tier 2	AS	CS
NMVOC	Tier 2	AS	CS
CO	Tier 2	AS	CS
SO_2	Tier 2	AS	CS

The 2006 IPCC Guidelines do not specify this category, and thus no pertinent decision tree is available.

3.3.1.3.1 Category description (solid fuel transformation)

Activity data

Table 69: activity data for processed products [figures in tonnes]

	1990	1995	2000	2005	2010	2012	2013
Lignite briquettes	40,045,000	5,010,829	1,819,263	1,489,922	2,024,103	1,928,000	1,951,000
Lignite granulate	59,000	0	0	0	0	0	0
Lignite coke	3,355,937	191,883	179,453	173,443	175,932	170,000	161,000
Lignite dust	3,791,431	2,700,110	2,678,926	2,923,620	3,632,333	4,158,000	4,318,000
Dried lignite	694,693	569,973	0	0	0	0	0
Fluidized-bed lignite	265,000	470,692	560,822	659,906	414,855	526,000	544,000
Hard-coal briquettes	756,000	379,000	146,000	91,625	0	0	0
Hard-coal coke	17,580,000	11,102,000	9,115,000	8,397,000	8,171,000	8,050,000	8,273,000

(STATISTIK DER KOHLENWIRTSCHAFT coal-sector-statistics association, n.y.).

Emission factors

The methane emission factor used for calculation of CH_4 emissions from hard-coal-coke production (coking plants) is 0.049 kg methane per tonne of hard-coal coke [DMT 2005]. It is used for the entire time series. The CO_2-emission factor is determined on the basis of the conservative assumption that about 1% of the coke is lost, in the form of fugitive emissions, between the time the blast-furnace door is opened and the coke is quenched. The activity data used consists of the total relevant quantities of hard-coal and lignite coke.

The emission factors for the non-greenhouse gases have been obtained from the research project "Emission factors for the iron and steel industry, for purposes of emissions reporting" ("Emissionsfaktoren zur Eisen- und Stahlindustrie für die Emissionsberichterstattung"), BFI 2011, FKZ 3707 42 301.

Table 70: Emission factors for the production of hard-coal coke

Gas	Emission factor	Units
CH_4	0.049	kg/t
CO_2	2,777[35]	kg/t
CO	0.015	kg/t
NH_3	243.3	mg/t
NMVOC	0.310	kg/t
SO_2	0.076	kg/t

No methane emissions are to be expected from processing of lignite products, since the EF used for 1.B.1.a.ii corresponds to the gas content of the lignite occurring in Germany. The other identified emissions are based on measurements made by the sole (at present) German producer of lignite coke at the Fortuna-Nord hearth-furnace plant.

Small quantities of charcoal are produced in Germany – by one major charcoal-factory operator and in a number of demonstration charcoal kilns. The pertinent quantities are determined by the Federal Statistical Office (StaBA) and are subject to confidentiality requirements. The relevant emission factors have been obtained from US_EPA 1995 ["AP 42, Fifth Edition, Volume I – Chapter 10: Wood Products Industry"]. Use of charcoal is reported under 2.G.4.

[35] The emission factor covers the area of production of hard-coal and lignite coke

Emissions and trend

Table 71: Emissions in category 1.B.1.b – solid fuel transformation

Gas	Total emissions			Trend		Remark
	1990	2012	2013	Since 1990	With respect to the previous year	
Methane	2.3 kt	2.1 kt	2.4 kt	3 %	14 %	The methane emissions are affected primarily by charcoal production. Emissions from coking plants have decreased since 1990, as a result of reductions in production. Production – and thus emissions – increased slightly with respect to the previous year, however.
Carbon dioxide	1,833 kt	703 kt	726 kt	-60 %	3 %	Emissions have decreased since 1990, as a result of reductions in coke production. Production – and thus emissions – increased slightly with respect to the previous year, however.

3.3.1.3.2 Methodological aspects (solid fuel transformation)

Emissions from hard-coal-coke production have been calculated via the Tier 2 method, in a manner similar to that of the IPCC Reference Manual's equation for CH_4 emissions from coal mining:

Emissions [kt CH_4] =

EF [m^3 CH_4 /t] * $AR_{transformation\ product}$* conversion factor [kt/$10^6m^3$]

3.3.1.3.3 Uncertainties and time-series consistency (solid fuel transformation)

The uncertainties for the emission factors for processing of coal have been estimated by experts as 10% to 25%.

For the activity data, a consistent source is used throughout the entire time series.

3.3.1.3.4 Category-specific quality assurance / control and verification (solid fuel transformation)

In consideration of emission factors, the IPCC conversion factor of 0.67 Gg/10^6m^3 at 20°C and 1 atmosphere should be applied to the units used in Germany: normal cubic metres at 1.01325 bar and 0°C [DIN 2004, DIN No. 1343]. The German practice of using normal cubic metres should also be noted in consideration of the IPCC default EF, and of figures from other published sources. In use of EF data published in Germany, it is assumed that the relevant figures use normal cubic metres [substantiated via survey of experts at the NaSE workshop 11/2004].

The guideline figures are oriented to 20°C and 1,013 mbar. In keeping with methane's isobaric proportionality, the factor 1.07 can be used to convert Nm^3 into m^3.

Conversion factor, normal cubic metres ⇔ kilogrammes:

0.717 Nm^3/kg (1.01325 bar, 0°C) **= 0.67 Gg/10^6m^3** (20°C, 1 atmosphere) * **1.07 Nm^3/m^3**

No comparisons with the corresponding data of other countries are possible in this category, since the pertinent CRF tables do not yield the required precise quantities and compositions of the transformed coal products involved. What is more, the IPCC Guidelines provide neither methods nor default emission factors for such a comparison in this category.

3.3.1.4 Category-specific recalculations (1.B.1 all)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

3.3.1.5 Planned improvements (category-specific) (1.B.1 all)

No further improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

3.3.2 Oil and natural gas and fugitive emissions from energy production (1.B.2)

This category is subdivided as follows:

Category				Included emissions
1.B.2. Oil, natural gas and fugitive emissions from energy production				
	a	**Oil**		
		i)	**Exploration**	Total emissions from exploratory drilling for oil and gas
		ii)	**Production**	Fugitive emissions from oil production and from oil processing (separation of water and accompanying gases)
		iii)	**Transport**	Emissions from transport of crude oil via pipelines and inland-waterway tankers
		iv)	**Refining / storage**	Emissions from oil desulphurisation and refining, from storage of crude oil and petroleum products and from cleaning of storage tanks
		v)	**Distribution of oil products**	Emissions from distribution of petroleum products, from refueling processes and drip losses and from cleaning of tanks of transport vehicles
		vi)	**Other**	No emissions in this category
	b	**Gas**		
		i)	**Exploration**	The emissions are assigned to category 1.B.2.a.i, since no differentiation is possible
		ii)	**Production**	Fugitive emissions from natural gas production
		iii)	**Processing**	Emissions from desulphurisation and processing of sour gas and from processing of town gas
		iv)	**Transport**	Emissions from long-distance high-pressure pipelines and from underground gas storage (caverns and porous-rock reservoirs)
		v)	**Distribution**	Emissions from natural-gas distribution lines, and from above-ground storage facilities, and fugitive leaks from tanks of vehicles for natural-gas transport
		vi)	**Other**	Fugitive emissions from residential installations, and from institutional, commercial and industrial users – emissions from service lines (house connection lines) are listed under 1.B.2.b.v, while emissions from natural-gas ignition in appliances are listed under 1.A.4

Category				Included emissions
	c	Venting and flaring		
		i)	Venting	
			Oil	The emissions are included in the categories 1.B.2.a.iii and 1.B.2.a.v
			Natural gas	The emissions are included in the categories 1.B.2.b.iv and 1.B.2.b.v
			Combined	No emissions in this category
		ii)	Flaring	
			Oil	Flaring emissions related to oil production and refining
			Natural gas	Flaring emissions related to natural gas production and to processing of sour gas
			Combined	No emissions in this category
	d	Other		
		i)	Geothermal energy	No fugitive CO_2, CH_4 or N_2O emissions occur in ongoing operations. Fugitive F-gas emissions are assigned to the category 2.F.9
1.C CO_2 – transport and storage				No emissions are being reported at present in this category, since no CCS measures are currently taking place in Germany.

3.3.2.1 Oil (1.B.2.a)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/-	1.B.2.a Fugitive Emissions from Fuels: Oil	Liquid Fuels	CH4	402,2	(0,03%)	234,8	(0,03%)	-41,6%
-/-	1.B.2.a Fugitive Emissions from Fuels: Oil	Liquid Fuels	CO2	281,7	(0,02%)	310,8	(0,03%)	10,3%

The category 1.B.2.a. "Oil" is not a key category.

3.3.2.1.1 "Oil, Exploration" (1.B.2.a.i)

Natural gas	Method used	Source for the activity data	Emission factors used
CO_2, CH_4	Tier 1	AS	D
NMVOC	Tier 2	AS	CS

3.3.2.1.1.1 Category description, "Oil, exploration" (1.B.2.a.i)

This category's emissions consist of emissions from activities of drilling companies and of other participants in the exploration sector. Gas and oil exploration takes place in Germany. The pertinent statistics do not differentiate between drilling solely for oil and drilling solely for natural gas.

Activity data

Table 72: Number of exploratory wells (sum total for oil and natural gas)

1990	1995	2000	2005	2010	2012	2013
12	17	15	23	16	26	22

(Annual report of the WEG oil and gas industry association, 2014).

Table 73: Total length of all exploratory wells (sum total for oil and natural gas)

1990	1995	2000	2005	2010	2012	2013
50,140 m	109,187 m	41,378 m	63,994 m	51,411 m	71,424 m	43,423 m

(Annual report of the WEG oil and gas industry association, 2014).

Emission factors

Table 74: Emission factors used for category 1.B.2.a.i

Gas	Emission factor	Method	Source
CO_2	0.48 kg / No	Tier 1	IPCC GPG 2000
CH_4	64 kg / No	Tier 1	IPCC GPG 2000
NMVOC	576 kg / No	Tier 2	Expert estimate

The emission factors given in IPCC GL 2006 (Table 4.2.4) refer to production quantities and not to exploratory wells. Therefore, those factors cannot be used in the present context.

Emissions and trend

Table 75: Emissions in category 1.B.2.a.i

Gas	Total emissions			Trend		Remark
	1990	2012	2013	Since 1990	With respect to the previous year	
Methane	768 kg	1,664 kg	1,408 kg	83 %	- 15 %	The emissions have increased with respect to their level in 1990, as a result of increased drilling.
Carbon dioxide	5.76 kg	12.48 kg	10.56 kg	83 %	- 15 %	
NMVOC	6,912 kg	14,976 kg	12,672 kg	83 %	- 15 %	

3.3.2.1.1.2 Methodological aspects, category "Oil, exploration" (1.B.2.a.i)

According to the WEG, virtually no fugitive emissions occur in connection with drilling operations, since relevant measurements are regularly carried out at well sites (with use of methane sensors in wellhead-protection structures, ultrasound measurements and annulus manometers), and since old / decommissioned wells are backfilled and normally covered with concrete caps.

Since pertinent measurements are not available for the individual wells involved, a conservative approach is used whereby well emissions (WEG 2012) are calculated on the basis of the default factor pursuant to IPCC GPG 2000 for carbon dioxide and methane, using the Tier 1 method.

3.3.2.1.1.3 Uncertainties and time-series consistency, category "Oil, exploration" (1.B.2.a.i)

The uncertainties in the activity data for oil and gas exploration have been quantified as +/- 5 %. The emission factors are assigned the default uncertainties from the Good Practice Guidance 2000, +/- 25 %.

For the activity data and the emission factors, a consistent source is used throughout the entire time series.

3.3.2.1.1.4 Category-specific quality assurance / control and verification, category "Oil, exploration" (1.B.2.a.i)

General quality control and a quality assurance have been carried out by source-category experts and the Single National Entity, according to the QSE-Handbook.

Due to a lack of country-specific data, an external assessment (Müller-BBM, 2009a) was commissioned. In its category analysis, that assessment found that the default factors are applicable to Germany. It was not possible to carry out a comparison with the results for other countries, because the relevant data lack basic comparability – for example, they use a range of units that are not mutually convertible.

3.3.2.1.2 "Oil, production and preprocessing" (1.B.2.a.ii)

Gas	Method used	Source for the activity data	Emission factors used
CO_2, CH_4	Tier 2	AS	CS
NMVOC	Tier 2	AS	CS

3.3.2.1.2.1 Category description, "Oil, production and preprocessing" (1.B.2.a.ii)

This category's emissions are produced in the petroleum industry's extraction (crude oil) and pre-treatment of raw materials (petroleum). Because Germany's oil fields are old, oil production in Germany is highly energy-intensive (thermal extraction, operation of pumps to inject water into oil-bearing layers).

The first treatment that extracted petroleum (crude oil) undergoes in processing facilities serves the purposes of removing gases, water and salt from the oil. Crude oil in the form in which it appears at wellheads contains impurities, gases and water, and thus does not conform to requirements for safe, easy transport in pipelines. No substance transformations take place. Impurities – especially gases (petroleum gas), salts and water – are removed, in order to yield crude oil of suitable quality for transport in pipelines.

Activity data

Table 76: Quantity of oil produced

1990	1995	2000	2005	2010	2012	2013
3,606 kt	2,959 kt	3,113 kt	3,573 kt	2,516 kt	2,623 kt	2,638 kt

(Annual report of the WEG oil and gas industry association, 2014).

Emission factors

Table 77: Emission factors used for production and processing

Gas	Emission factor	Method	Source
CO_2	88.5 g/m³	Tier 2	Expert estimate
CH_4	90.4 g/m³	Tier 2	Expert estimate
NMVOC	9.1 g/m³	Tier 2	Expert estimate

Emissions and trend

Table 78: Emissions in category 1.B.2.a.ii

Gas	Total emissions			Trend		Remark
	1990	2012	2013	Since 1990	With respect to the previous year	
Methane	1,081 t	83 t	276 t	-92 %	330 %	The emissions have decreased with respect to 1990, as a result of decreasing production and improved emissions-reduction technologies in the areas of production and processing.
Carbon dioxide	460 t	278 t	271 t	-41 %	- 3 %	
NMVOC	108 t	36 t	28 t	-74 %	- 22 %	

3.3.2.1.2.2 Methodological aspects of the category "Oil, production and preprocessing" (1.B.2.a.ii)

The emissions from production and processing are measured, or calculated, by the operators, and the pertinent data are published in the annual reports of the WEG oil and gas industry association. The emission factors are determined from the reported emissions and the activity data shown in Table 76.

The emissions are calculated in keeping with the Tier 2 method.

3.3.2.1.2.3 Uncertainties and time-series consistency in the category "Oil, production and preprocessing" (1.B.2.a.ii)

In this category, the uncertainty for the activity data is given as 5 to 10 %. The figures are based on estimates of WEG experts and national experts.

The uncertainties for the emission factors in the category amount to 25 %.

3.3.2.1.2.4 Category-specific quality assurance / control and verification for the category "Oil, production and preprocessing" (1.B.2.a.ii)

General quality control and a quality assurance have been carried out by source-category experts and the Single National Entity, according to the QSE-Handbook.

The emission factors that have been used are of the same order of magnitude as those given in the 2006 IPCC Guidelines.

Table 79: Comparison of IEF with the relevant IPCC default values

Gas	CS emission factor used	IPCC GL 2006 (Table 4.2.4)	
	Units in [g/m³]	Units in [Gg/1000m³]	Units in [g/m³]
CO_2	88.5 g/m³	$1.1*10^{-07}$ to $2.6*10^{-04}$	0.11 – 260.00
CH_4	90.4 g/m³	$1.5*10^{-06}$ to $6.0*10^{-02}$	1.50 – 60,000
NMVOC	9.1 g/m³	$1.8*10^{-06}$ to $4.5*10^{-03}$	1.80 – 4500.0

3.3.2.1.3 "Oil, transport" (1.B.2.a.iii)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	AS	CS
NMVOC	Tier 2	AS	CS

3.3.2.1.3.1 Category description, "Oil, transport" (1.B.2.a.iii)

This category's emissions are tied to activities of logistics companies and of operators of pipelines and pipeline networks. Following first treatment, crude oil is transported to refineries.

Almost all transports of crude oil take place via pipelines. Pipelines are stationary and, normally, run underground. In contrast to other types of transports, petroleum transports are not interrupted by handling processes.

Activity data

Table 80: Transports of domestically produced crude oil

1990	1995	2000	2005	2010	2012	2013
3,606 kt	2,959 kt	3,113 kt	3,573 kt	2,516 kt	2,623 kt	2,638 kt

(Annual report of the WEG oil and gas industry association, 2014).

Table 81: Transports of imported crude oil

1990	1995	2000	2005	2010	2012	2013
84,043 kt	86,063 kt	89,280 kt	97,474 kt	98,084 kt	97,677 kt	104,662 kt

(Annual report of the WEG oil and gas industry association, 2014).

Table 82: Crude oil transports via inland-waterway tankers

1990	1995	2000	2005	2010	2012	2013
88.9 kt	66.6 kt	111.8 kt	176.4 kt	5.6 kt	45.6 t	72.0 kt

(Federal Statistical Office, Fachserie 8 / Reihe 4, Table 2.1).

Emission factors

Table 83: Emission factors used for category 1.B.2.a.iii, "Transport of crude oil"

Category	Activity data	Units	Gas	Emission factor (EF)	Units
Transports of imported crude oil	97.68	Millions of t/a	NMVOC	0.055	kg/t
			CH_4	0.0055	
Transports of domestically produced crude oil	2.62		NMVOC	0.11	
			CH_4	0.011	

Emissions and trend

Table 84: Emissions in category 1.B.2.a.iii

Gas	Total emissions 1990	2012	2013	Trend Since 1990	With respect to the previous year	Remark
NMVOC	5,090 t	5,732 t	6,135 t	21 %	7 %	The increasing trend is driven primarily by increases in the quantities of transported oil.
CH_4	502 t	566 t	605 t	21 %	7%	

3.3.2.1.3.2 Methodological aspects of the category "Oil, transport" (1.B.2.a.iii)

The emissions are calculated in keeping with the Tier 2 method.

For pipelines, the emission factor for methane has been taken from the 2006 IPCC Guidelines, while for inland-waterway tankers that factor has been estimated by experts. The pertinent emission factors have been confirmed by the research project Theloke et al "Determination of emission factors and activity data in areas 1.B.2.a.i through vi" ("Ermittlung von Emissionsfaktoren und Aktivitätsraten im Bereich 1.B.2.a.i bis vi" (2013)). Since long-distance pipelines are continually monitored, and since disruptive incidents in such pipelines are very rare (CONCAWE – "Performance of European cross country oil pipelines"), emissions occur – in small quantities – only at their transfer points. The emission factor is thus highly conservative.

The emission factor covers the areas of transfer / injection into pipelines at pumping stations, all infrastructure (connections, control units, measuring devices) along pipelines and transfer at refineries, and it has been determined on the basis of conservative assumptions. For imported quantities, only one transfer point (only the withdrawal station) is assumed, since the station for input into the pipeline network does not lie on Germany's national territory.

3.3.2.1.3.3 Uncertainties and time-series consistency in the category "Oil, transport" (1.B.2.a.iii)

The uncertainties for the emission factors have been quantified as +/- 20 %, while those for the activity data have been determined to be +/- 10 %. The emission factors and the activity data are consistent throughout the entire time series.

3.3.2.1.3.4 Category-specific quality assurance / control and verification for the category "Oil, transport" (1.B.2.a.iii)

General quality control and a quality assurance have been carried out by source-category experts and the Single National Entity, according to the QSE-Handbook.

The emission factors that have been used are of the same order of magnitude as those given in the 2006 IPCC Guidelines.

Table 85: Comparison of IEF with the relevant IPCC default values

Gas	CS emission factor used Units in [g/m³]	IPCC GL 2006 (Table 4.2.4) Units in [Gg/1000m³]	Units in [g/m³]
NMVOC	6 g/m³	$5.4*10^{-06}$	5.4
CH_4	55 g/m³	$5.4*10^{-05}$	54.0

3.3.2.1.4 "Oil, refining and storage" (1.B.2.a.iv)

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	AS	CS
CH_4	Tier 2	AS	CS
SO_2	Tier 2	AS	CS
CO	Tier 2	AS	CS
NO_x	Tier 2	AS	CS
NMVOC	Tier 2	AS	CS

3.3.2.1.4.1 Category description, "Oil, refining and storage" (1.B.2.a.iv)

This category's emissions consist of emissions from activities of refineries and of refining companies in the petroleum industry. Crude oil and intermediate petroleum products are processed in Germany. For the most part, the companies concerned receive crude oil for refining and processing. Such processing takes place in state-of-the-art plants.

Refinery tank storage systems are used to store both crude oil and intermediate and finished petroleum products. They thus differ from non-refinery tank storage systems in terms of both the products they store and the quantities they handle. Tank-storage facilities outside of refineries are used especially for interim storage of heating oil, petrol and diesel fuel.

Tanks are emptied and cleaned for purposes of tank inspections and repairs. In tank cleaning, a distinction is made between crude-oil tanks and product tanks. Because of the sediment deposits involved, cleaning of crude-oil tanks, in comparison to cleaning of product tanks, is a considerably more involved process. Product tanks contain no sedimentable substances and thus are cleaned only when the products they contain are changed. In keeping with an assessment of [Müller-BBM, 2009b], the emission factors for storage of crude oil and petroleum products may be assumed to take cleaning processes into account.

Activity data

Table 86: Quantity of crude oil refined

1990	1995	2000	2005	2010	2012	2013
107,058 kt	96,475 kt	107,632 kt	114,589 kt	95,398 kt	95,836 kt	90,935 kt

(2014 annual report of the Association of the German Petroleum Industry (MWV)).

Table 87: Utilisation of refineries' capacity

1990	1995	2000	2005	2010	2012	2013
106.2 %	92.1 %	95.3 %	99.5 %	81.1 %	91.8 %	88.6 %

(Internal calculation of the Federal Environment Agency (UBA); 2014 annual report of the Association of the German Petroleum Industry (MWV)).

Table 88: Crude-oil-distillation capacity in refineries

1990	1995	2000	2005	2010	2012	2013
100,765 kt	104,750 kt	112,940 kt	115,630 kt	117,630 kt	104,397 kt	102,635 kt

(2014 annual report of the Association of the German Petroleum Industry (MWV)).

Table 89: Storage capacity of tank-storage facilities in refineries and pipeline terminals

1990	1995	2000	2005	2010	2012	2013
27.2 million m^3	28.4 million m^3	24.9 million m^3	24.0 million m^3	22.5 million m^3	22.6 million m^3	22.6 million m^3

(MWV 2014; own survey).

Table 90: Storage capacity of tank-storage facilities not located at refineries

1990	1995	2000	2005	2010	2012	2013
41.9 million m^3	41.2 million m^3	46.0 million m^3	44.2 million m^3	43.2 million m^3	43.9 million m^3	43.9 million m^3

(MWV 2014; own survey).

Emission factors

Table 91: Emission factors used for category 1.B.2.a.iii, "Fugitive emissions at refineries"

Gas	Emission factor	Method	Source
CH_4	0.647 g/t	Tier 2	Expert estimate
CO	0.598 g/t	Tier 2	Expert estimate
CO_2	594.001 g/t	Tier 2	Expert estimate
SO_2	0.439 g/t	Tier 2	Expert estimate
NMVOC	24.647 g/t	Tier 2	Expert estimate
NO_x	0.001 g/t	Tier 2	Expert estimate

Table 92: Emission factor used for category 1.B.2.a.iii, "Anode production at refineries"

Gas	Emission factor	Method	Source
CO_2	207.4 kg/t	Tier 2	Expert estimate

Table 93: Emission factors used for category 1.B.2.a.iii, "Storage and cleaning of crude oil in tank-storage facilities of refineries"

Gas	Emission factor	Method	Source
CH_4	0.016 kg/t	Tier 2	Expert estimate
NMVOC	0.144 kg/t	Tier 2	Expert estimate

Table 94: Emission factors used for category 1.B.2.a.iii, "Storage of liquid petroleum products in tank-storage facilities outside of refineries"

Gas	Emission factor	Method	Source
CH_4	5 g/m^3	Tier 2	Expert estimate
NMVOC	100 g/m^3	Tier 2	Expert estimate

Table 95: Emission factors used for category 1.B.2.a.iii, "Storage of gaseous petroleum products in tank-storage facilities outside of refineries"

Gas	Emission factor	Method	Source
CH_4	150 g/m^3	Tier 2	Expert estimate
NMVOC	500 g/m^3	Tier 2	Expert estimate

Emissions and trend

Table 96: Emissions in category 1.B.2.a.iv

Gas	Total emissions 1990	Total emissions 2012	Total emissions 2013	Trend Since 1990	Trend With respect to the previous year	Remark
Carbon dioxide	217,671 t	243,808 t	256,525 t	18 %	5 %	The trend for CO_2 is influenced by anode production. The falling trend for methane and NMVOC is driven by improved emissions-reduction technologies in refineries and in storage of refinery products.
Methane	14,502 t	8,540 t	8,509 t	- 41 %	0 %	
NMVOC	97,183 t	41,386 t	41,132 t	- 58 %	- 1%	

3.3.2.1.4.2 Methodological aspects of the category "Oil, refining and storage" (1.B.2.a.iv)

The emissions for all sub-areas are calculated in keeping with the Tier 2 method.

Refining

The emission factors used for NMVOC, CH_4, CO_2, CO, NO_x and SO_2 were obtained from evaluations, carried out by Theloke et. al. (2013), of the 2004 and 2008 emissions declarations.

Anode production

The activity data are calculated from the relevant quantity of petroleum coke, minus the own consumption (coke burn-off in catalyst regeneration – cf. 1.A.2). The data have been obtained from the Official Mineral Oil Statistics [BAFA 2014]. This "green coke" is processed via calcining. The emission factor is calculated from the pertinent activity data and from the emissions data of the EU Emissions Trading System (ETS).

Tank-storage facilities in refineries

In keeping with the results of the research project "Processing of data of emissions declarations pursuant to the 11th Ordinance Implementing the Federal Immission Control Act – the area of storage facilities" ("Aufbereitung von Daten der Emissionserklärungen gemäß 11. BImSchV - Bereich Lageranlagen") [Müller-BBM, 2009b], the crude-oil-distillation capacity is used as the activity data for estimation of emissions from storage in refineries. The fugitive-VOC-emissions value specified in VDI Guideline 2440, 0.16 kg/t, may be used as the emission factor. The EF for methane was derived from it (5-10 % of 0.16 kg) and then suitably deducted.

Tank-storage facilities outside of refineries

According to Müller-BBM (2009b), no emission factors can be derived, via evaluation of emissions declarations for storage systems, that would be representative of individual systems. This is due, so the same source, to the clearly widely differing emissions behaviour of different individual systems. It was possible, however, to form aggregated emission factors. For each relevant group of data, this was done by correlating the sums of all emissions with the sums of all capacities. For non-refinery tank-storage systems, storage of liquid petroleum products can be differentiated from storage of gaseous petroleum products, since the relevant data are suitably differentiated.

3.3.2.1.4.3 Uncertainties and time-series consistency in the category "Oil, refining and storage" (1.B.2.a.iv)

Uncertainties of +/ 20 % are assumed for the emission factors for refining of crude oil. The uncertainties for the activity data are assumed to be +/- 10 %. The total uncertainties for the emissions from the area of storage and cleaning are estimated at +/- 40 %. These figures are based on estimates of national experts, and on the research report of Müller-BBM (2009b) and Theloke et. al. (2013).

The emission factors and the activity data are consistent throughout the entire time series.

3.3.2.1.4.4 Category-specific quality assurance / control and verification for the category "Oil, refining and storage" (1.B.2.a.iv)

General quality control and a quality assurance have been carried out by source-category experts and the Single National Entity, according to the QSE-Handbook.

Due to the complexity of the category, the data cannot be cross-checked against those of other countries. This was confirmed at the 2014 EU Workshop in Dessau. To permit comparison with the IPCC Guidelines, the factors for refining and crude oil storage were summed.

Table 97: Comparison of IEF with the relevant IPCC default values

Source	Gas	CS emission factor used	IPCC GL 2006 (Table 4.2.4)	
		Units in [g/m³]	Units in [Gg/1000m³]	Units in [g/m³]
Storage	CH_4	13.8		
Refining	CH_4	0.56		
Total	**CH_4**	**14.4**	**$2.6*10^{-06}$ - $41.0*10^{-06}$**	**2.6 - 41.0**
Storage	NMVOC	124.1		
Refining	NMVOC	21.5		
Total	**NMVOC**	**145.6**	**0.0013**	**1,300**

The emission factor for methane lies within the range of the default value given in the IPCC Guidelines. While the factor for NMVOC is an order of magnitude lower, the relevant default value has an uncertainty of +/- 100%. The factor in the EMEP Guidebook (Table 3-1) is 0.2 kg/t, which corresponds to 172 g/m³ and thus is of the same order of magnitude as the German emission factor.

3.3.2.1.5 "Oil, distribution of oil products" (1.B.2.a.v)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	AS	CS
NMVOC	Tier 2	AS	CS

3.3.2.1.5.1 Category description, "Oil, distribution of oil products" (1.B.2.a.v)

The category comprises transports and handling of petroleum products, via inland-waterway tankers, pipelines, railway tank cars and road tankers, as well as cleaning of transport vehicles.

Activity data

Table 98: Petrol stations in Germany (number)

1990	1995	2000	2005	2010	2012	2013
19,317	17,957	16,324	15,187	14,744	14,678	14,622

(MWV 2014).

Table 99: Distributed quantities of petroleum products (figures in kilotonnes)

	1990	1995	2000	2005	2010	2012	2013
Diesel fuel	21,817	26,208	28,922	28,531	32,128	33,678	34,840
Jet fuel	4,584	5,455	6,939	8,049	8,465	8,658	8,802
Light heating oil	31,803	34,785	27,875	25,380	21,005	18,710	19,829
Petrol	31,257	30,333	28,833	23,431	19,634	18,487	18,422

(MWV 2014).

Table 100: Petroleum transports via inland-waterway tankers

1990	1995	2000	2005	2010	2012	2013
3,000 kt	3,000 kt	3,000 kt	2,783 kt	6,358 kt	4,369 kt	5,058 kt

(Federal Statistical Office, Fachserie 8, Reihe 4, Table 2.1; data for the period prior to 2001 are estimates of the Federal Environment Agency (UBA)).

Emission factors

The emission factors listed below have been verified by the study [Theloke et al 2013]. The model used for calculation of petrol emissions is described in Chapter 3.3.2.1.5.2.

Petroleum products are transported by inland-waterway tanker ships, product pipelines, railway tank cars and road tankers, and they are transferred from tanks to other tanks. Experts consider the emissions from refueling of aircraft to be non-existent, since the equipment used for such refueling is fitted with dry couplings. The emissions from filling of private heating-oil tanks are also very low, thanks to high safety standards.

In this category, petroleum products are handled and distributed that have undergone fractional distillation in refineries, i.e. processes in which gaseous products are separated out. For this reason, no significant methane emissions are expected. Only in storage of certain petroleum products can small quantities of methane escape.

Table 101: NMVOC emission factors used for category 1.B.2.a.v "Distribution of petrol"

Process responsible for emissions	Emission factor [kg/t]	Method	Source
Drip losses in refueling at petrol stations	0.117 kg/t	Tier 2	Expert estimate
Transfers from road tankers to petrol stations (20th Ordinance Implementing the Federal Immission Control Act – vapour displacement)	1.4[36] kg/t	M (Tier 2)	Expert estimate
Ventilation in connection with transports with inland-waterway tankers	0.025 kg/t	Tier 2	Expert estimate
Transfers from petrol station tanks to vehicle tanks (21st Ordinance Implementing the Federal Immission Control Act – vapour recovery)	1.4 kg/t	M (Tier 2)	Expert estimate

Table 102: NMVOC emission factors used for category 1.B.2.a.v "Distribution of diesel fuel"

Process responsible for emissions	Emission factor [kg/t]	Method	Source
Drip losses in refueling at petrol stations	0.1 kg/t	Tier 2	Expert estimate
Transports from refineries to transport vehicles	0.008 kg/t	Tier 2	Expert estimate
Transfers from petrol station tanks to vehicle tanks	0.003 kg/t	Tier 2	Expert estimate

Table 103: NMVOC emission factors used for category 1.B.2.a.v "Distribution of light heating oil"

Process responsible for emissions	Emission factor [kg/t]	Method	Source
Drip losses in refueling at transfer stations	0.0011 kg/t	Tier 2	Expert estimate
Transports from refineries to transport vehicles	0.0053 kg/t	Tier 2	Expert estimate
Transfers from petrol station tanks to vehicle tanks	0.0063 kg/t	Tier 2	Expert estimate

Table 104: NMVOC emission factors used for category 1.B.2.a.v "Distribution of jet fuels"

Process responsible for emissions	Emission factor [kg/t]	Method	Source
Drip losses in refueling at transfer stations	0 kg/t	Tier 2	Expert estimate
Transports from refineries to transport vehicles	0.055 kg/t	Tier 2	Expert estimate
Transfers from petrol station tanks to vehicle tanks	0.02 kg/t	Tier 2	Expert estimate

[36] The factor does not include reduction measures – cf. Table 106

Emissions and trend

Table 105: Emissions in category 1.B.2.a.v

Gas	Total emissions 1990	2012	2013	Trend Since 1990	With respect to the previous year	Remark
NMVOC	110.5 kt	28.1 kt	28.0 kt	- 75 %	0 %	The emissions decreases are due primarily to the introduction of the 20th and 21st Ordinances Implementing the Federal Immission Control Act (BImSchV), which phased in requirements for vapour-balancing and vapour-recovery systems.

3.3.2.1.5.2 Methodological aspects, "Oil, distribution of oil products" (1.B.2.a.v)

Transport

Inland-waterway tankers that transport petrol retain considerable quantities of petrol vapours in their tanks after their petrol has been unloaded. When the ships change loads or spend time in port, their tanks have to be ventilated. With such ships averaging 277 instances of ventilation per year, the quantity of NMVOC emitted in such operations amounts to 336 - 650 t [BIPRO 2010]. The highest value in the range is used for calculation of the relevant emissions.

About 13 million m³ of petrol fuels are transported annually in Germany via ***railway tank cars***. Transfer/handling (filling/unloading) and tank losses result in annual emissions of only 1,400 t VOC [UBA 2004b]. The emissions situation points to the high technical standards that have been attained in railway tank cars and pertinent handling facilities.

Petrol stations

Significant quantities of fugitive VOC emissions are released into the environment during transfers from tanker vehicles to storage facilities and during refueling of vehicles. For emissions determination, a standardised emission factor of 1.4 kg/t is used. This refers to the saturation concentration for hydrocarbon vapours – and, thus, corresponds to the maximum possible emissions level in the absence of reduction measures.

The immission-control-law provisions of 1992 and 1993 (20th and 21st BImSchV – 20th and 21st Ordinances Implementing the Federal Immission Control Act), designed to limit such emissions at petrol stations, promoted relevant reduction measures. The relevant provisions cover the areas of both transfer and storage of petrol (20th BImSchV) and of refueling of vehicles with petrol at petrol stations (21st BImSchV).

Use of required emissions-control equipment, such as vapour-balancing (20th BImSchV) and vapour-recovery (21st BImSchV) systems, along with use of automatic monitoring systems (via the amendment of the 21st BImSchV on 6 May 2002), have brought about continual reductions of VOC emissions; the relevant high levels of use of such equipment are shown in the table below (Table 106).

In emissions calculation, the two ordinances' degrees of application to the petrol stations in service, and their efficiencies, are taken into account. The following assumptions, based on the technical options currently available, are applied:

Table 106: Effectiveness of the 20th and 21st Ordinances Implementing the Federal Immission Control Act (BImSchV), and their resulting effects on petrol stations

Ordinance		Factor	
20th BImSchV	Vapour balancing	Level of use Efficiency	98 % 98 %
21st BImSchV	Vapour recovery	Level of use Efficiency	98 % 85 %

The emissions are calculated with the following formula:

Emissions = activity data * unreduced emission factor (from Table 101) * (level of use * (1 - efficiency) + (1 - level of use))

Cleaning of transport vehicles

Tank interiors are cleaned prior to tank repairs, prior to safety inspections, in connection with product changes and with lease changes.

The inventory currently covers cleaning of railway tank cars. The residual amounts remaining in railway tank cars' tanks after the tanks have been emptied – normally, between 0 and 30 litres (up to several hundred litres in exceptional cases) – are not normally able to evaporate completely. They thus produce emissions when the insides of tanks are cleaned.

Each year, some 2,500 cleaning operations are carried out on railway tank cars that transport petrol. The emissions released, via exhaust air, in connection with cleaning of tank cars' interiors amount to about 40,000 kg/a VOC [UBA 2004b, p.34].

Any additional prevention and reduction measures could affect emissions in this category only slightly. At the same time, emissions can be somewhat further reduced from their current levels via a combination of various technical and organizational measures. Emissions during handling – for example, during transfer to railway tank cars – are produced especially by residual amounts of petrol that remain after tanks have been emptied. Such left-over quantities in tanks can release emissions via manholes the next time the tanks are filled. Study is thus underway to determine the extent to which "best practice" is being followed at all handling stations, and whether this extent has to be taken into account in emissions determination. In addition, improvements of fill nozzles enhance efficiency in prevention of VOC emissions during refueling.

Pursuant to the UBA text (2004b), a total of 1/3 of all relevant transports are carried out with railway tank cars. The remaining 2/3 of all transports are carried out by other means – primarily with road tankers.

The 1/3 to 2/3 relationship given by the report is assumed to be also applicable to the emissions occurring in connection with cleaning. Currently, the inventory includes 36,000 kg of NMVOC emissions from cleaning of railway tank cars. Emissions from cleaning of other transport equipment – primarily road tankers – are derived from that figure; they amount to about 70,000 kg NMVOC.

More thorough emissions collection upon opening of manholes of railway tank cars (a volume of about 14.6 m³ escapes), along with more thorough treatment of exhaust from cleaning of tanks' interiors, could further reduce VOC emissions. Exhaust cleansing is assumed to be carried out via one-stage active-charcoal adsorption. For an initial load of 1 kg/m³, exhaust concentration levels can be reduced by 99.5 %, to less than 5 g/m³. As a result, the remaining emissions amount to only 1.1 t. This is equivalent to a reduction of about 97 % [UBA, 2004b, p. 34] from the determined level of 36.5 t/a (without adsorption).

3.3.2.1.5.3 Uncertainties and time-series consistency, "Oil, distribution of oil products" (1.B.2.a.v)

The uncertainties in the category are quantified as follows: for the emission data, +/- 20% (95 % confidence interval, normal distribution); for the activity data, +/- 5% [Theloke et.al. 2013].

3.3.2.1.5.4 Category-specific quality assurance / control and verification for the category "Oil, distribution of oil products" (1.B.2.a.v)

General quality control and a quality assurance have been carried out by source-category experts and the Single National Entity, according to the QSE-Handbook.

The data cannot be compared with those of other countries, since the CRF tables do not indicate what factors influenced the reported emissions. What is more, in the 2013 submission only Spain and Sweden reported NMVOC emissions in this category. With regard to methane emissions, IEF can be derived only for Iceland and Croatia. No cross-checking against the 2006 IPCC Guidelines is possible, since those Guidelines do not list any default factors.

3.3.2.2 Natural gas (1.B.2.b)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/-/2	**1.B.2.b Fugitive Emissions from Fuels: Natural Gas**	**Gaseous Fuels**	**CH4**	**9.266,1**	**(0,76%)**	**7.429,0**	**(0,79%)**	**-19,8%**
-/-	1.B.2.b Fugitive Emissions from Fuels: Natural Gas	Gaseous Fuels	CO2	1.405,6	(0,12%)	1.598,3	(0,17%)	13,7%

The category 1.B.2.b "Natural gas" is a key category for CH_4 emissions in terms of emissions level and of Tier 2 analysis.

3.3.2.2.1 "Natural gas, exploration" (1.B.2.b.i)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	IE	IE	IE
NMVOC	IE	IE	IE

3.3.2.2.1.1 Category description, "Natural gas, exploration" (1.B.2.b.i)

Category 1.B.2.b.i is considered together with category 1.B.2.a.i (Oil, exploration). Consequently, the aggregated, non-subdivided data of 1.B.2.b.i are included in category 1.B.2.a.i.

3.3.2.2.1.2 Methodological aspects of the category "Natural gas, exploration" (1.B.2.b.i)

The possibility of breaking exploration down into oil exploration and natural gas exploration was reviewed [Öko 2014], but then abandoned due to a lack of statistics and to the very small emissions quantities involved. The emissions are thus listed completely, for both oil exploration and gas exploration, under 1.B.2.a.i.

3.3.2.2.1.3 Uncertainties and time-series consistency, category "Natural gas, exploration" (1.B.2.b.i)

See 1.B.2.a.i for explanations of uncertainties and time-series consistency.

3.3.2.2.1.4 Category-specific quality assurance / control and verification, category "Natural gas, exploration" (1.B.2.b.i)

General and category specific quality control and a quality assurance have been carried out by source-category experts and the Single National Entity, according to the QSE-Handbook.

See 1.B.2.a.i for an explanation of category-specific quality assurance / control and verification.

3.3.2.2.2 "Natural gas, production" (1.B.2.b.ii)

Gas	Method used	Source for the activity data	Emission factors used
CO_2, CH_4	Tier 2	AS	CS
NMVOC	Tier 2	AS	CS

3.3.2.2.2.1 Category description, "Natural gas, production" (1.B.2.b.ii)

The emissions of this category consist of emissions related to production.

Activity data

Table 107: Produced quantities of natural gas

1990	1995	2000	2005	2010	2012	2013
15.3 billion m³	19.1 billion m³	20.1 billion m³	18.8 billion m³	12.7 billion m³	10.8 billion m³	9.8 billion m³

(Annual report of the WEG oil and gas industry association, 2014).

Emission factors

Table 108: Emission factors used for production

Gas	Emission factor	Method	Source
CO_2	0.12 g/m³	Tier 2	Expert estimate
CH_4	0.19 g/m³	Tier 2	Expert estimate
NMVOC	0.01 g/m³	Tier 2	Expert estimate

Emissions and trend

Table 109: Emissions in category 1.B.2.b.ii

Gas	Total emissions			Trend		Remark
	1990	2012	2013	Since 1990	With respect to the previous year	
Methane	5,799 t	2,152 t	1,889 t	- 67 %	- 12 %	The emissions have decreased with respect to 1990, as a result of decreasing production and improved emissions-reduction technologies.
Carbon dioxide	1,450 t	1,356 t	1,135 t	- 22 %	- 16 %	
NMVOC	580 t	108 t	127 t	- 78 %	18 %	

3.3.2.2.2.2 Methodological aspects of the category, "Natural gas, production" (1.B.2.b.ii)

Since 1998, the WEG oil and gas industry association has determined the emissions from production and published the relevant data in its annual report. For the period prior to 1998, the emissions have been determined with the help of default factors from the 2006 IPCC Guidelines. The emissions are calculated in keeping with the Tier 2 method.

3.3.2.2.2.3 Uncertainties and time-series consistency of the category "Natural gas, production" (1.B.2.b.ii)

In this category, the uncertainty for the activity data is given as 5 %. The figures are based on estimates of WEG experts and national experts.

The uncertainties for the emission factors in the category amount to 10 %.

3.3.2.2.2.4 Category-specific quality assurance / control and verification, category "Natural gas, production" (1.B.2.b.ii)

General and category specific quality control and a quality assurance have been carried out by source-category experts and the Single National Entity, according to the QSE-Handbook.

The emission factors that have been used are of the same order of magnitude as those given in the 2006 IPCC Guidelines.

Table 110: Comparison of IEF with the relevant IPCC default values

Gas	CS emission factor used Units in [g/m³]	IPCC GL 2006 (Table 4.2.5) Units in [Gg/106m³]	 Units in [g/m³]
CO_2	0.12 g/m³	$1.4*10^{-05}$ to $1.8*10^{-04}$	0.014 – 0.18
CH_4	0.19 g/m³	$3.8*10^{-04}$ to $2.4*10^{-02}$	0.380 – 24.0
NMVOC	0.01 g/m³	$9.1*10^{-05}$ to $1.2*10^{-03}$	0.091 – 1.20

3.3.2.2.3 Natural gas, processing (1.B.2.b.iii)

Gas	Method used	Source for the activity data	Emission factors used
CO_2, CH_4	Tier 2	AS	CS
CO	Tier 1	AS	CS
SO_2, NMVOC	Tier 2	AS	CS

3.3.2.2.3.1 Category description (1.B.2.b.iii)

The emissions of this category consist of emissions from the activities of pretreatment and processing.

After being brought up from underground reserves, natural gas is first treated in drying and processing plants. As a rule, such pretreatment of the natural gas takes place in facilities located directly at the pumping stations. Such processes separate out associated water from reserves, along with liquid hydrocarbons and various solids. Glycol is then used to remove the water vapour remaining in the gas [WEG 2008a[37], p. 25]. Natural gas dehydration systems are closed systems. For safety reasons, all of such a system's overpressure protection devices are integrated within a flare system. When such protection devices are triggered, the surplus gas is guided to a flarehead, where it can be safely burned. After drying, the natural gas is ready for sale and can be delivered to customers directly, via pipelines [EXXON 2014]. The relevant quantities of flared gas are reported under 1.B.2.c.

The natural gas drawn from Germany's Zechstein geological formation contains hydrogen sulphide. In this original state, the gas – known as "sour gas" – has to be subjected to special treatment. Such gas is transported via separate, specially protected pipelines (due the hazardousness of hydrogen sulphide) to German processing plants that wash out its hydrogen sulphide via chemical and physical processes. About 40 % of the natural gas extracted in Germany is sour gas [WEG 2008].

The natural gas that leaves processing plants is ready for use. The hydrogen sulphide is converted into elementary sulphur and is used primarily by the chemical industry, as a basic raw material.

[37] WEG 2008a: Erdgas-Erdöl, Entstehung-Suche-Förderung, Hannover, 34 p.

Activity data

Table 111: Sulphur production from natural gas production in Germany

1990	1995	2000	2005	2010	2012	2013
915 kt	1,053 kt	1,100 kt	1,050 kt	832 kt	798 kt	755 kt

(Annual report of the WEG oil and gas industry association, 2014).

Figures for natural gas production are presented in Chapter 3.3.2.2.2.1, in Table 107.

Emission factors

Table 112: Emission factors used for category 1.B.2.b.iii, "Processing"

Gas	Emission factor	Method	Source
NMVOC	0.01 kg / 1,000 m³	Tier 2	Association data
CH_4	0.13 kg / 1,000 m³		
CO_2	408 kg / 1,000 m³		

Emissions and trend

Table 113: Emissions in category 1.B.2.b.iii

Gas	Total emissions			Trend		Remark
	1990	2012	2013	Since 1990	With respect to the previous year	
Methane	5,614 t	1,291 t	1,271 t	- 77 %	- 2 %	The air-pollution emissions of the exploration and production industry are determined in keeping with a procedure accepted throughout the industry[38]. For this reason, the annual emissions figures vary somewhat from year to year and do not yield a straight line. The sharp increase in NMVOC emissions is due to a change of methods.
Carbon dioxide	1,404 kt	1,571 kt	1,597 kt	14 %	2 %	
NMVOC	31 t	97 t	98 t	316 %	1 %	

3.3.2.2.3.2 Methodological issues (1.B.2.b.iii)

The emissions were calculated in keeping with the Tier 2 method.

For processing of sour gas, the WEG data for the period since 2000 are used. Those data are the result of the WEG members' own measurements and calculations. For the period prior to 2000, the average CO_2 emission factor reported by Austria, 0.23 t / 1,000 m³, is used, since, according to the WEG, the German desulphurisation plant is comparable to the Austrian plant.

For calculation of emissions from sour-gas processing, a split factor of 0.4 relative to the activity data is applied. That split factor is based on the WEG report on sour-gas processing [WEG, 2008a].

3.3.2.2.3.3 Uncertainties and time-series consistency (1.B.2.b.iii)

For the emissions data, the category uncertainties are given as 10 to 30 %. Those figures are based on estimates of national experts, and they lie within the range listed for relevant default emission factors [IPCC GPG 2000, Chapter 2.7.1.6.].

3.3.2.2.3.4 Category-specific quality assurance / control and verification (1.B.2.b.iii)

General and category specific quality control and a quality assurance have been carried out by source-category experts and the Single National Entity, according to the QSE-Handbook.

[38] WEG: "Leitfaden zu Erfassung der Umweltdaten der WEG Mitgliedsfirmen", published in-house, and last revised in Sept. 2006

Table 114: Comparison of IEF with the relevant IPCC default values

Source	CS emission factor used Units in [g/m³]	2006 IPCC GL (Table 4.2.4)[39] Units in [Gg/10⁶m³]	Units in [g/m³]
CO_2	408	$7.9*10^{-06}+ 3.6*10^{-3}+ 6.3*10^{-2}$	66.608
CH_4	0.13	$9.7*10^{-05} + 2.4*10^{-6}$	0.099
NMVOC	0.01	$6.8*10^{-05} + 1.9*10^{-6}$	0.068

A comparison with the IPCC default factors [Table 4.2.4 in the 2006 IPCC GL] shows that the national emission factors for methane lie within the range given for the default factors. The factor for carbon dioxide greatly exceeds the relevant default factor, however. Nonetheless, Germany's value in this category is of the same order of magnitude as Austria's. No cross-checking against the corresponding figures of other countries could be carried out, since the CRF tables do not indicate what shares of processed natural gas must be assigned to the "sour gas" category.

Table 115: Comparison of emission factors for carbon dioxide

Source	CS emission factor used Units in [g/m³]
Austria	230
Germany	408

3.3.2.2.4 Gas, transmission (1.B.2.b.iv)

Gas	Method used	Source for the activity data	Emission factors used
CH_4 (transmission)	Tier 3	AS	CS
CH_4 (storage)	Tier 2	AS	CS

3.3.2.2.4.1 Category description (1.B.2.b.iv)

This category's emissions consist of emissions from activities of gas producers and suppliers. In Germany, natural gas is transported from production and processing companies/plants to gas suppliers and other processors. In addition, natural gas is imported and transmitted via high-pressure pipelines.

Almost all of the pipelines used to transmit natural gas are steel pipelines [DBI 2014a].

Activity data

Table 116: Length of long-distance high-pressure pipelines [km]

1990	1995	2000	2005	2010	2012	2013
22,696	29,866	32,214	34,086	35,503	35,681	35,575

[Own survey]

Some of the natural gas is stored in underground reservoirs to permit, and guard against, interruptions of pipeline transports.

Table 117: Volumes of underground gas-storage facilities [figures in billlions of cubic metres]

	1990	1995	2000	2005	2010	2012	2013
Cavern reservoirs	2.8	4.8	6.1	6.8	9.2	12.1	13.2
Porous-rock reservoirs	5.2	8.5	12.5	12.4	12.1	10.8	10.6

[Annual report of the WEG oil and gas industry association, 2014].

One important emissions pathway consists of the compressors that are used to maintain pressure in pipelines. They are spaced at intervals of about 100 km along lines [GASUNIE

[39] Addition of fugitive emissions, flare emissions and raw-CO_2 venting

2014]. At present, the compressors involved have a total power output of about 2,550 MW [personal communication, DBI 2014). The pipelines also contain shut-off devices (sliding sleeves), safety mechanisms located at intervals of about 20 km along high-pressure pipelines.

Emission factors

Some of the gas extracted in Germany is moved via pipelines from gas fields and their pumping stations (either on land or offshore). The companies that operate the most important long-distance gas pipelines in Germany are all members of the *Wirtschaftsverband Erdöl- und Erdgasgewinnung German oil and gas industry association* (WEG), the *German Technical and Scientific Association for Gas and Water* (DVGW) and the *German Association of Energy and Water Industries (BDEW)*.

Table 118: Emission factors used for methane emissions in category 1.B.2.a.iv, "Transmission"

System or mechanism	Value	Method	Source
Long-distance, high-pressure steel pipeline	62 kg/km	Tier 3	Expert estimate
Long-distance, high-pressure plastic pipeline	0.3 kg/km	Tier 3	Expert estimate
Compressor	38,000 m³/MW	Tier 2	Expert estimate
Sliding sleeve hub	46,845 m³/No.	Tier 2	Expert estimate
Cavern reservoirs	0.05 kg / 1,000 m³ (Vn)[40]	Tier 2	Expert estimate
Porous-rock reservoirs	0.05 kg / 1,000 m³ (Vn)[41]	Tier 2	Expert estimate

Emissions and trend

Table 119: Emissions in category 1.B.2.b.iv

Gas	Total emissions			Trend		Remark
	1990	2012	2013	Since 1990	With respect to the previous year	
Methane	72.9 kt	128.2 kt	131.2 kt	75 %	2 %	The emissions have been increasing as a result of addition of new long-distance high-pressure pipelines, including the attendant compressors and safety mechanisms.

3.3.2.2.4.2 Methodological issues (1.B.2.b.iv)

The emissions from natural gas transmission were calculated in keeping with the Tier 3 method.

The emissions from natural gas storage, from compressor stations and from sliding sleeve hubs were calculated in keeping with the Tier 2 method.

The emission factor for underground natural gas storage was derived via surveys of operators and analysis of statistics on accidents / incidents [Müller-BBM 2012], and it is valid for pore-storage and cavern-storage facilities. It is seen as very conservative. The emission factor for

[40] Available volume of working gas, normed to 273 K and 1013 hPa.

[41] Available volume of working gas, normed to 273 K and 1013 hPa.

the compressor systems and the sliding sleeve hubs has been obtained from the research project DBI 2014b.

Results for above-ground gas storage facilities are reported in 1.B.2.b.v.

3.3.2.2.4.3 Uncertainties and time-series consistency (1.B.2.b.iv)

For the emissions data, the category uncertainties are given as 10 to 30 %. Those figures are based on estimates of national experts, and they lie within the range listed for relevant default emission factors (IPCC GPG 2000, Chapter 2.7.1.6.). For underground storage facilities, an uncertainty of -50% is assumed, since the factors used were obtained via a highly conservative approach.

3.3.2.2.4.4 Category-specific quality assurance / control and verification (1.B.2.b.iv)

General and category specific quality control and a quality assurance have been carried out by source-category experts and the Single National Entity, according to the QSE-Handbook.

A comparison of the category with the relevant IPCC default factors (Table 4.2.8) indicates that the emission factors for methane lie within the range given.

Table 120: Comparison of IEF with the relevant IPCC default values

System or mechanism	CS emission factor	2006 IPCC GL – Table 4.2.8
Compressor	38,000 m³/MW	6,000 – 100,000 m³/MW
Shut-off devices (sliding sleeve hubs)[42]	46,845 m³/No.	1,000 – 50,000 m³/No

The emission factors for the compressors and the shut-off devices lie within the range for the pertinent IPCC factors. All of the emission factors used have been verified via a number of projects [STOLLER, DBI 2012, DBI 2014a and DBI 2014b].

3.3.2.2.5 Natural gas, distribution (1.B.2.b.v)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 3	AS	CS

3.3.2.2.5.1 Category description (1.B.2.b.v)

This category's emissions consist of emissions from activities of companies that supply gas to customers. In Germany, natural gas is distributed to users primarily via pipeline networks. Gas is distributed via low-pressure pipelines (with pressure up to 100 mbar), medium-pressure pipelines (with pressure between 100 mbar and 1 bar) and high-pressure pipelines (>1 bar), made of special plastics, steel / ductile-cast iron and grey cast iron.

The emissions caused by gas distribution have decreased slightly, even though gas throughput has increased considerably and the distribution network has been enlarged considerably with respect to its size in 1990. One important reason for this improvement is that the gas-distribution network has been modernised, especially in eastern Germany. In particular, the share of grey cast iron lines in the low-pressure network has been reduced, with such lines being supplanted by low-emissions plastic pipelines. Another reason for the reduction is that fugitive losses in distribution have been reduced through a range of technical improvements (tightly sealing fittings such as flanges, valves, pumps, compressors) undertaken in keeping

[42] The emission factor is calculated from the data for the components blow pump and armature (DBI 2014b)

with emissions-control provisions in relevant regulations [TA Luft 1986 and 2002; VDI-Richtlinie (VDI Guideline) 2440, 11-2000].

Activity data

Table 121: Gas-distribution network

Parameter	1990	1995	2000	2005	2010	2012	2013
Total length of pipeline network[43] [km]	282,612	366,987	417,354	466,302	470,396	480,594	487,165

[131. Gasstatistik 2011; own survey]

Table 122: Number of natural-gas-powered vehicles in Germany

	1990	1995	2000	2005	2010	2012	2013
Number	0	0	7,500	28,500	90,000	96,284	98,172

[Federal Motor Transport Authority; own survey]

Emission factors

System or mechanism	Value	Method	Source
Low-pressure pipeline made of steel and ductile cast iron	372 kg/km	Tier 3	Expert estimate
Low-pressure plastic pipeline	51 kg/km	Tier 3	Expert estimate
Low-pressure grey-cast-iron pipeline	445 kg/km	Tier 3	Expert estimate
Medium-pressure pipeline made of steel and ductile cast iron	207 kg/km	Tier 3	Expert estimate
Medium-pressure plastic pipeline	28 kg/km	Tier 3	Expert estimate
High-pressure pipeline made of steel and ductile cast iron	62 kg/km	Tier 3	Expert estimate
High-pressure plastic pipeline	0.3 kg/km	Tier 3	Expert estimate
Above-ground storage facilities	5 kg / 1,000 m³ (Vn)[44]	Tier 2	Expert estimate
Gas-pressure-regulation (meauring) equipment	250 m³/a	Tier 2	Expert estimate
Natural-gas-powered vehicles	0.33 kg / vehicle	Tier 2	Expert estimate

Emissions and trend

Table 123: Emissions in category 1.B.2.b.v

Gas	Total emissions			Trend		Remark
	1990	2012	2013	Since 1990	With respect to the previous year	
Methane	255.9 kt	131.9 kt	134.2 kt	-48 %	2 %	The emissions have been decreasing as a result of use of emissions-reducing materials in the pipeline network – and, especially, via replacement of grey-cast-iron pipes

3.3.2.2.5.2 Methodological issues (1.B.2.b.v)

Pipeline network

The calculation was carried out using the Tier 3 method, on the basis of the available network statistics of the German Association of Energy and Water Industries (BDEW) and of our own surveys. In the early 1990s, emissions from distribution of town gas were also taken into account in calculations. In 1990, the town-gas distribution network accounted for a total of 16 %

[43] The data given include building-connection lines

[44] Available volume of working gas, normed to 273 K and 1013 hPa.

of the entire gas network. Of that share, 15 % consisted of grey cast iron lines and 84 % consisted of steel and ductile cast iron lines.

The emission factors for the distribution network were verified in 2012 [STOLLER, DBI 2012] and 2014 [DBI 2014].

The emission factor used, 250 m³ / station for the gas-pressure-regulation (-measuring) systems in the distribution network, was determined by Federal Environment Agency experts on the basis of data from the DBI study 2014b.

Storage reservoirs

Man-made above-ground storage facilities, for storage of medium-sized quantities of natural gas, help meet and balance rapid fluctuations in demand. In Germany, spherical and pipe storage tanks, and other types of low-pressure containers, are used for this purpose. Results from a relevant research project [Müller-BBM 2012] have made it possible to derive new country-specific emission factors for this area. The emissions have been calculated in accordance with the Tier 2 method.

Natural-gas-powered vehicles, and CNG fueling stations

Use of vehicles running on natural gas continues to increase in Germany. Such vehicles are refueled at CNG fueling stations connected to the public gas network. In such refueling, compressors move gas from high-pressure on-site tanks. Some 900 CNG fueling stations are now in operation nationwide [Müller-BBM 2012]. In keeping with the stringent safety standards applying to refueling operations and to the tanks themselves, the pertinent emissions are very low – about 30 t per year. In the main, emissions result via tank pressure tests and emptying processes. The emissions have been calculated in accordance with the Tier 2 method.

Liquefied natural gas (LNG)

Natural gas can be liquefied, at a temperature of -161°C, for ease of transport. The liquefaction process is highly energy-intensive, however, and is normally used only in connection with long-distance transports. Germany has no LNG terminals at present [Müller-BBM 2012]. Gas imports arrive mostly in gaseous form, via long-distance pipelines, and they are included in 1.B.2.b.iv.

Germany now has one natural gas liquefaction facility and two satellite LNG storage facilities. Since the storage and transfer processes at those facilities are subject to the most stringent standards possible, emissions there can be ruled out. Gas can escape only in connection with maintenance work, and the gas quantities involved are extremely small. The quantities do not exceed more than a few hundred kilograms [Müller-BBM 2012].

3.3.2.2.5.3 Uncertainties and time-series consistency (1.B.2.b)

For the emissions data, the category uncertainties are given as 20-30 %. Those figures are based on estimates of experts, and they lie within the range listed for relevant default emission factors [IPCC GL 2006, Table 4.2.4].

3.3.2.2.5.4 Category-specific quality assurance / control and verification (1.B.2.b.v)

General and category specific quality control and a quality assurance have been carried out by source-category experts and the Single National Entity, according to the QSE-Handbook.

It was not possible to compare the results for this category with the corresponding results of other countries, due to a lack of convertibility of pertinent units.

Table 124: Comparison of IEF with the relevant IPCC default values

Method	EF	AD	EM
CS (only the distribution network)	124 kg/km[45]	487,165 km	60 kt
IPCC 2006	1.1 * 10^{-3} Gg / millions of m³	92 billion m³	101 kt

Both methods yield emissions on the same order of magnitude. The IPCC default factor is somewhat higher – presumably, since it includes the gas-pressure-regulation systems.

3.3.2.2.6 Natural gas, other leakage (1.B.2.b.vi)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	AS	CS

3.3.2.2.6.1 Category description (1.B.2.b.vi)

The category describes emissions from leakage in the industrial sector and in the residential, institutional and commercial sector. The activity data are based on results of the German Association of Energy and Water Industries (BDEW) ("Gasstatistik" – gas statistics) and of our own surveys.

Activity data

Table 125: Activity data used for category 1.B.2.b.vi, "Fugitive emissions at sites of natural gas use"

	1990	1995	2000	2005	2010	2012	2013
Number of gas meters in the residential, institutional and commercial category [millions]	10.3	12.7	12.8	13.3	12.9	12.9	12.9
Energy consumption of industry [TWh]	323	361	370	399	335	353	353

[BDEW; own survey]

Emission factors

Table 126: Methane emission factors used for category 1.B.2.b.vi, "Fugitive emissions at sites of natural gas use"

Operational site	Gas	Value	Method	Source
Gas meters and fittings in the residential, institutional and commercial sectors	CH_4	2 m³/No[46]	Tier 2	Expert estimate
Fittings in industrial facilities	CH_4	0.4 m³ / 1,000 m³	Tier 2	Expert estimate

[45] Weighted EF

[46] Average factor with respect to natural gas loss per number of gas meters in residences

Emissions and trend

Table 127: Emissions in category 1.B.2.a.vi

Gas	Total emissions 1990	2012	2013	Trend Since 1990	With respect to the previous year	Remark
Methane	29.1 kt	27.3 kt	27.3 kt	- 6%	0 %	The decrease is due to a reduction in the number of gas-fired devices (especially gas stoves), as well as to use of equipment with lower emissions.

3.3.2.2.6.2 Methodological issues (1.B.2.b.v)

The emission factors are country-specific, and they were determined via the research project "Methanemissionen durch den Einsatz von Gas in Deutschland von 1990 bis 1997 mit einem Ausblick auf 2010" ("Methane emissions via gas use in Germany from 1990 to 1997, with an outlook for 2010"); Frauenhofer ISI, 2000. Pursuant to the regulations DIN EN 1359, 3376-1, 3376-2, and to the gas-tightness tests they require, a maximum permissible value of 1-5 l/h can be derived. The relevant values were obtained at a pressure of 1.5 times the operational pressure. National experts thus consider a value of 2 m^3/year to be suitable. The emissions that occur during ignition of end-user devices have already been included under 1.A.4. Emissions resulting from leakages in end-user service (connecting) lines are included, for statistical reasons, in 1.B.2.b.iv.

The emissions are calculated in keeping with the Tier 2 method.

3.3.2.2.6.3 Uncertainties and time-series consistency (1.B.2.b)

For the emissions data, the category uncertainties are given as 20 %. That figure is based on estimates of experts, and it lies within the range listed for relevant default emission factors [IPCC GPG 2000, Chapter 2.7.1.6.].

3.3.2.2.6.4 Category-specific quality assurance / control and verification (1.B.2.b.v)

General and category specific quality control and a quality assurance have been carried out by source-category experts and the Single National Entity, according to the QSE-Handbook.

VERICO SCE 2014 compared the results for this category with other countries' corresponding results. This comparison yielded considerable differences between Germany's results and those of neighbouring countries. While a number of countries have emissions in this category, other countries' results are, on average, two orders of magnitude smaller than the German results. While the 2006 IPCC Guidelines provide no method description for this category, their Table 4.2.8 presents a range for the expected emissions.

Table 128: Comparison of IEF with the relevant IPCC default values

System or mechanism	CS emission factor	2006 IPCC GL – Table 4.2.8
Losses at the point of use	2 m^3/No.[47]	2 to 20 m^3/No.

[47] It was not possible to include the emission factor for industry emissions within the comparison, since the relevant units cannot be converted.

3.3.2.3 Venting and flaring (1.B.2.c)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/-	1.B.2.c Venting and Flaring	0	CO2	543,5	(0,04%)	367,8	(0,04%)	-32,3%
-/-	1.B.2.c Venting and Flaring	0	CH4	1,6	(0,00%)	2,6	(0,00%)	57,6%
-/-	1.B.2.c Venting and Flaring	0	N2O	1,1	(0,00%)	0,2	(0,00%)	-83,8%

The categories in the overarching group of fugitive emissions from 1.B.2.c "Venting and flaring" cover greenhouse-gas and pollutant emissions either vented or flared directly into the atmosphere. The emissions from venting processes are included in the category 1.B.2.a.iv for oil, and in categories 1.B.2.b.iii and 1.B.2.b.iv for natural gas.

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	AS	CS
CH_4	Tier 2	AS	CS
N_2O	Tier 2	AS	CS
NMVOC	Tier 2	AS	CS

The category 1.B.2.c "Venting and flaring" is not a key category.

3.3.2.3.1.1 Category description, "Venting and flaring" (1.B.2.c)

Pursuant to general requirements of the Technical Instructions on Air Quality Control (TA Luft; 2002), gases, steam, hydrogen and hydrogen sulphide released from pressure valves and venting equipment must be collected in a gas-collection system. Wherever possible, gases so collected are burned in process combustion. Where such use is not possible, the gases are piped to a flare. Flares used for flaring of such gases must fulfill at least the requirements for flares for combustion of gases from operational disruptions and from safety valves. For refineries and other types of plants in categories 1.B.2, flares are indispensable safety components. In crude-oil refining, excessive pressures can build up in process systems, for various reasons. Such excessive pressures have to be reduced via safety valves, to prevent tanks and pipelines from bursting. Safety valves release relevant products into pipelines that lead to flares. Flares carry out controlled burning of gases released via excessive pressures. When in place, flare-gas recovery systems liquify the majority of such gases and return them to refining processes or to refinery combustion systems. In the process, more than 99 % of the hydrocarbons in the gases are converted to CO_2 and H_2O. When a plant has such systems are in operation, therefore, its flarehead will seldom show more than a small pilot flame.

Activity data

Table 129: Refined quantity of crude oil

1990	1995	2000	2005	2010	2012	2013
107 million t	96 million t	108 million t	115 million t	95 million t	96 million t	91 million t

(Annual report of the Association of the German Petroleum Industry (MWV), 2014).

Emission factors

Flaring takes place at extraction and pumping systems and in refineries. In refineries, flaring operations are subdivided into regular operations and start-up / shut-down operations in connection with disruptions.

Table 130: Emission factors used for category 1.B.2.c, "Flaring emissions in natural gas extraction"

Gas	Value	Method	Source
CO_2	1.777 kg/m³	Tier 2	Expert estimate
NO	$2*10^{-8}$ kg/m³	Tier 1	IPCC default value

Table 131: Emission factors used for category 1.B.2.c., "Flaring emissions at petroleum production facilities"

Gas	Value	Method	Source
CO_2	9.1 kg/t	Tier 2	Expert estimate
N_2O	0.55 g/t	Tier 1	IPCC default value

Methane and NMVOC emissions are included under production. Pursuant to the WEG oil and gas industry association, the pertinent nitrous oxide emissions are extremely insignificant. In the interest of maintaining a conservative approach, the IPCC default value has been used in the relevant calculation.

Table 132: Emission factors used for category 1.B.2.c "Flaring emissions at refineries: normal flaring operations"

Gas	Value	Method	Source
CH_4	0.29 g/t	Tier 2	Expert estimate
CO_2	2.86 kg/t	Tier 2	Expert estimate
N_2O	0.01 g/t	Tier 2	Expert estimate
CO	0.33 g/t	Tier 2	Expert estimate
NMVOC	2.80 g/t	Tier 2	Expert estimate
SO_2	8.43 g/t	Tier 2	Expert estimate
NO_X (as NO_2)	0.41 g/t	Tier 2	Expert estimate

Table 133: Emission factors used for category 1.B.2.c "Flaring emissions at refineries: disruptions of flaring operations"

Gas	Value	Method	Source
CH_4	0.08 g/t	Tier 2	Expert estimate
CO_2	1.28 kg/t	Tier 2	Expert estimate
N_2O	0.3 mg/t	Tier 2	Expert estimate
CO	4.16 g/t	Tier 2	Expert estimate
NMVOC	2.27 g/t	Tier 2	Expert estimate
SO_2	15.23 g/t	Tier 2	Expert estimate

NO_X (as NO_2)	3.49 g/t	Tier 2	Expert estimate

The emission factors have been derived from the 2004 and 2008 emissions declarations (Theloke et al 2013).

Emissions and trend

Table 134: Emissions in category 1.B.2.c "Venting and flaring"

Gas	Total emissions 1990	2012	2013	Trend Since 1990	With respect to the previous year	Remark
Methane	66 t	113 t	104 t	58 %	-8 %	Emissions from flaring systems have decreased continuously as a result of improvements in gas-recovery methods.
Carbon dioxide	544 kt	399 kt	368 kt	-32 %	-8 %	
NMVOC	521 t	446 t	408 t	-22 %	-9 %	

3.3.2.3.1.2 Methodological aspects, "Venting and flaring" (1.B.2.c)

Venting emissions are taken into account in category 1.B.2.b.iii. The SO_2 emissions are obtained from the activity data of 11,648,000 m³ of flared natural gas [WEG 2013, p. 57] and an emission factor of 0.140 kg / 1,000 m³, a factor based on an average H_2S content of 5 % by volume.

The emission factors are determined on the basis of emissions reports, crude-oil-refining capacity and total capacity utilisation at German refineries. The guide for this work consists of the evaluation assessment of Theloke et al (2013).

The emissions are calculated in keeping with the Tier 2 method.

3.3.2.3.1.3 Uncertainties and time-series consistency, category "Venting and flaring" (1.B.2.c)

The quantitative uncertainties for the emission factors for flaring processes during normal operations are assumed to be +/-10 % (95 % confidence interval, normal distribution). The uncertainties for the activity data are assumed to be +/- 5 % (95 % confidence interval, normal distribution).

The uncertainties for the emission factors for disruption-related flaring processes (operations during disruptions; start-up / shut-down operations) are much larger, since the emissions quantities can vary widely from year to year. They are estimated at -90 % / +300 % (95% confidence interval, log-normal distribution). The uncertainties for the activity data are assumed to be +/- 10 % (95 % confidence interval, normal distribution) [Theloke et. al. 2013].

3.3.2.3.1.4 Category-specific quality assurance / control and verification, category "Venting and flaring" (1.B.2.c)

General quality control and a quality assurance have been carried out by source-category experts and the Single National Entity, according to the QSE-Handbook.

A comparison of the category with the IPCC Guidelines reveals considerable differences in individual factors. At the EU Workshop held in Dessau in 04/2014, the participating experts agreed that the default values are considerably higher than the emission factors currently used in Europe.

Table 135: Comparison of IEF with the relevant IPCC default values

Gas and system	CS emission factor used[48] Units in [g/m³]	IPCC GL 2006 (Table 4.2.4) Units in [Gg/1000m³]	Units in [g/m³]
CO_2 in refinery flares	3,569	$3.4*10^{-02}$	34,000
CH_4 in refinery flares	0.32	$2.1*10^{-05}$	21
NMVOC in refinery flares	4.37	$1.7*10^{-05}$	17
CO_2 in oil production systems	7844	$4.1*10^{-02}$	41,000
CO_2 in natural gas production systems	1532	$1.2*10^{-03}$	1,200

3.3.2.4 Geothermal energy (1.B.2.d)

3.3.2.4.1 Category description (1.B.2.d)

The category 1.B.2.d "Geothermal energy" is not a key category.

Geothermal energy is a renewable form of energy. Geothermal energy systems that tap geothermal heat to a depth of 400 metres are classified as "near-surface" geothermal energy systems. Near-surface geothermal systems generate heating and cooling energy by means of heat pumps. They are also used for heating service water. Geothermal energy systems that tap geothermal heat at depths greater than 400 metres are classified as "deep" geothermal energy systems. Geothermal heating stations use the heat in their thermal-water flows directly, and provide heating and cooling to end consumers, via district / local heating and cooling networks. Geothermal power stations convert the heat in their thermal-water flows into electricity. In most cases, they produce heat as well, via processes for combined heat/power (CHP) production.

As of the end of 2013, a total of 26 deep geothermal energy systems, with electricity output of 26.31 MW and thermal output of 244.40 MW, were in operation. A total of 11 systems, with electricity output of 31.6 MW and thermal output of 123.45 MW, are under construction. An additional 39 systems are planned, with planned capacity of 76 MW of electrical output and 402 MW of thermal output.

Operation of geothermal power stations and heat stations in Germany produces no emissions of climate-relevant gases. The thermal-water circuits of such installations are closed and airtight, both above and below ground level. As a result, no emissions occur during their operation. What is more, releases of the gases dissolved in their heat-carrying fluids – primarily H_2, CH_4, CO_2 and H_2S – would not produce concentrations that would require reporting (cf. "Umwelteffekte einer geothermischen Stromerzeugung, Analyse und Bewertung der klein- und großräumigen Umwelteffekte einer geothermischen Stromerzeugung" ("Environmental effects of geothermal power generation; analysis and assessment of small-scale and large-scale environmental impacts of geothermal power generation")), FKZ 205 42 110, Chapter A.2.3.5). For this reason, the emissions are reported as "NO". In 2013, all geothermal energy systems met their own power requirements (primarily power for operating pumps) by drawing electricity from the grid. In the report, that use is included in the relevant categories.

[48] For refineries, determined as a mean value between normal operation and operation during disruptions

3.3.2.4.2 Methodological issues (1.B.2.d)

The IPCC Reference Manual does not describe any methods for category 1.B.2.d "Other" (IPCC, 1996b: p. 1.132f).

No emission factors for greenhouse gases and pollutants that could escape in connection with drilling for tapping of geothermal energy (both near-surface and deep energy) are known for Germany at present. As is known from oil and gas exploration, however, it is clear that virtually any drilling will lead to releases of gases bound in underground layers – and the gases involved can include H_2, CH_4, CO_2, H_2S and Rn (cf. "Environmental effects of geothermal electricity production; analysis and assessment of the small-scale and large-scale environmental effects of geothermal electricity production", FKZ 205 42 110, Chapter A.2.1.5). Drilling to tap near-surface geothermal energy can be expected to produce only very slight emissions. In all drilling to tap deep geothermal energy, blow-out preventers are used to prevent gas releases. In addition, drilling fluids are used to drive any gases released into boreholes back into the rock layers traversed in drilling. THELOKE 2013 estimates that the fugitive emissions related to deep geothermal wells are on the order of kilograms. The emissions in this category are reported as NE, therefore, because their contribution to the total emissions is less than 0.05 % of the overall inventory or 500 kt CO_2 equivalents (pursuant to FCCC/SBSTA/2013/L.29/Add.1), and since it cannot be assured that annual inventories of such emissions (pursuant to FCCC/SBSTA/2013/L.29/Add.1, para 37) will be carried out. In Chapter 5, the pertinent emissions contribution to the overall inventory is presented (on a one-time basis). A compilation of all sources for which the entry "not estimated" is retained is presented in Annex 5 (Chapter 21).

3.3.2.4.3 Uncertainties and time-series consistency (1.B.2.d)

No explanations of uncertainties and time-series consistency are required.

3.3.2.4.4 Category-specific quality assurance / control and verification (1.B.2.d)

No explanations relative to category-specific quality assurance / control and verification are required.

3.3.2.5 Category-specific recalculations (1.B.2 all)

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

3.3.2.6 Planned improvements (category-specific) (1.B.2, all)

No further improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4 INDUSTRIAL PROCESSES (CRF SECTOR 2)

4.1 Overview (CRF Sector 2)

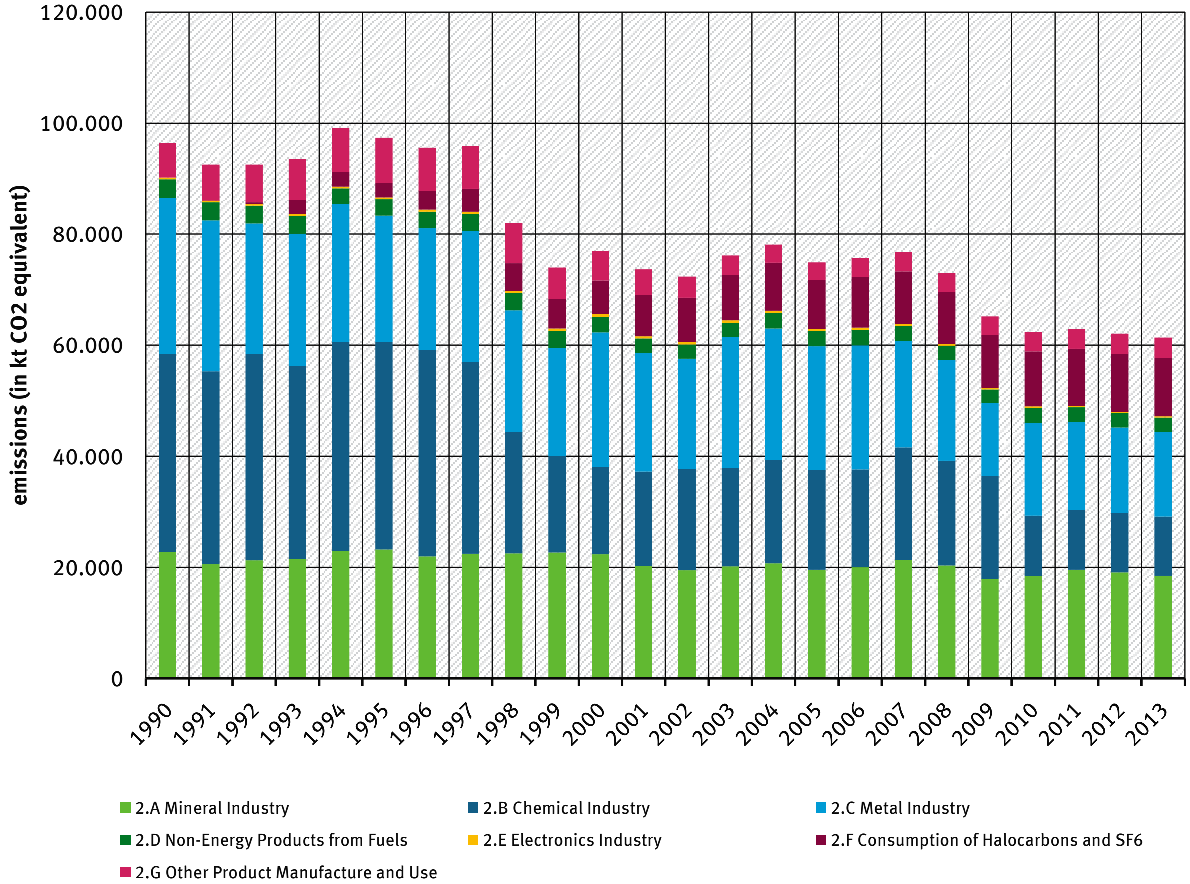

Figure 45: Overview of greenhouse-gas emissions in CRF Sector 2

4.2 Mineral industry (2.A)

The CRF category 2.A Mineral industry is divided into sub- categories 2.A.1 through 2.A.4. These fields include:

- cement clinker production (2.A.1),
- lime burning (2.A.2),
- glass production (2.A.3),
- ceramics production (2.A.4.a)
- other soda ash use (2.A.4.b),
- production of non-metallurgic magnesium products (2.A.4.c),
- other limestone and dolomite use (2.A.4.d),

4.2.1 Mineral industry: Cement production (2.A.1)

4.2.1.1 Category description (2.A.1)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/-	2A1 Mineral Products: Cement Production	Clinker Burning	CO_2	15,145.8	(1.24%)	12,257.8	(1.31%)	-19.1%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	AS	CS
NO_X, SO_2	Tier 1	AS	CS

The category *Cement* is a key category for CO_2 emissions in terms of emissions level. The remarks below refer only to production of cement clinkers, because clinker grinding is not relevant as a dust source in the present context. In Table 136, cement production is included solely for reference purposes, without emissions relevance in this context.

The clinker-burning process emits climate-relevant gases. CO_2 accounts for the great majority of these emissions. The CO_2 emissions from pertinent raw materials are tied directly to the quantities of cement clinkers that are produced. Pursuant to the *VDZ central organisation of the German cement industry* (VDZ, 2014), clinker production in 2013 amounted to 23,128 kt[49]. Raw-material-related CO_2 emissions are calculated with a country-specific emission factor, as determined by the VDZ from plant-specific data, of 0.53 t CO_2/t cement clinkers. Clinker production produced raw-material-related CO_2 emissions of 12,258 kt CO_2 in 2013.

Table 136: Production and CO_2 emissions in the German cement industry

Year	Clinker production [kt/a]	Emission factor [t CO_2/t]	Raw-material-related CO_2 emissions [kt/a]	Cement production (kt/a)
1990	28,577	0.53	15,146	37,772
1991	25,670		13,605	34,341
1992	26,983		14,301	37,331
1993	27,146		14,387	36,649
1994	28,658		15,189	40,512
1995	29,072		15,408	35,862
1996	27,669		14,664	34,318
1997	28,535		15,124	34,148
1998	29,039		15,391	35,601
1999	29,462		15,615	37,438
2000	28,494		15,102	35,414
2001	25,227		13,370	32,118
2002	23,954		12,696	31,009
2003	25,233		13,373	32,749
2004	26,281		13,929	31,854
2005	24,379		12,921	31,009
2006	24,921		13,208	33,630
2007	26,992		14,306	33,382
2008	25,366		13,444	33,581
2009	23,232		12,313	30,441
2010	22,996		12,188	29,915
2011	24,775		13,131	33,540
2012	24,581		13,028	32,432
2013	23,128		12,258	31,308

Source: derived from BDZ 2005 (until 1994); VDZ, 2014 (as of 1995)

[49] Provisional value (rounded off).

4.2.1.2 Methodological issues (2.A.1)

Activity data

Activity data are determined via summation of figures for individual plants (until 1994, activity data were determined on the basis of data of the BDZ German cement-industry association). As of 1995, following optimisation of data collection within the association, activity data have been compiled by the VDZ, and by its cement-industry research institute (located in Düsseldorf), via surveys of German cement works and use of BDZ figures. In the main, the data consist of data published in the framework of CO_2 monitoring, supplemented with data for plants that are not BDZ members (in part, also VDZ estimates). This corresponds to the Tier 2 approach of the IPCC Guidelines (IPCC, 2006d, Chap. 2.2).

Table 136 summarises the activity data for cement clinkers and cement, and the raw-material-related CO_2 emissions as determined from clinker production, for the years 1990 through 2013.

Emission factors

The emission factor used for emissions calculation, 0.53 t CO_2 / t cement clinkers, is based on mass-weighted figures for individual plants, i.e. the VDZ determined the emission factor by aggregating plant-specific data relative to fractions of CaO and other metal oxides (MgO; in raw materials, and containing carbonate) in clinkers. The emission factor was determined in the framework of a research project (VdZ, 2009), and it was confirmed by the VDZ in subsequent years. The procedure used corresponds to the Tier 2 method of the IPCC Guidelines (IPCC, 2006d), and it is considered to be more precise than utilisation of default emission factors.

In the German cement industry, dust separated from exhaust gas is returned to the burning process. As a result, carbonate release from clinker raw materials can be determined directly from clinkers' metal-oxide content, without any need to take account of significant losses via the exhaust-gas pathway.

The emission factor of 0.53 t CO_2 / t cement clinkers was applied to the entire time series.

Raw-material-related CO_2 emissions in the cement industry are determined, in accordance with the *IPCC-GPG*, via the following equation:

$$CO_2 \text{ emissions} = \text{emission factor } (EF_{clinkers}) \text{ x clinker production}$$

(Table 136 shows calculated CO_2 emissions for the German cement industry for the years covered by the report.)

4.2.1.3 Uncertainties and time-series consistency (2.A.1)

For the activity data, time-series consistency is assured by the long period of time over which the association has collected pertinent data; for the emission factor, it is assured via use of a standard approach for all relevant years.

The uncertainties given were determined via expert assessment.

Most companies are required to report clinker-production data within the framework of CO_2-emissions trading. The EU monitoring guidelines for emissions trading specify a maximum accuracy of 2.5 %. The uncertainties for the activity data used were thus estimated at -2.5 % and +2.5 %.

The uncertainty for the emission factor used was estimated at +/- 2 %. This was confirmed via surveys in the framework of a research project (VdZ, 2009).

4.2.1.4 Category-specific quality assurance / control and verification (2.A.1)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

For purposes of quality assurance, all data used, including data from the BDZ, from the VDZ and comparative data from the literature, were checked for plausibility. The emission factor determined for raw-material-related CO_2 emissions has been compared with the relevant figures of other countries. The small discrepancy (about 1 %) relative to the IPCC Tier 1 default factor, amounting to 0.52 t CO_2 / t clinkers (IPCC 2006d, Chap. 2.2, equation 2.4), results in that German clinkers often have a higher lime content.

The emission factor used differs only slightly from the average emission factors used in connection with the ETS in Germany, emission factors that are checked by authorities and reviewed in light of companies' obligations to provide records. To date, no calculations relative to the emission factor prior to the year 2000 are available. The same figure – the result of an expert assessment – has been used for all relevant years in that period.

4.2.1.5 Category-specific recalculations (2.A.1)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.2.1.6 Planned improvements (category-specific) (2.A.1)

No category-specific improvements are planned.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.2.2 Mineral products: Lime production (2.A.2)

4.2.2.1 Category description (2.A.2)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/-	**2.A.2 Mineral Products: Lime Production**	**burning of Limestone and Dolomite**	**CO_2**	**5,986.6**	**(0.49%)**	**4,811.3**	**(0.51%)**	**-19.6%**

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	AS	D
NO_X, SO_2	Tier 1	AS	CS

The category *Lime production* is a key category for CO_2 emissions in terms of emissions level.

The statements made below regarding category 2.A.2 refer solely to the amounts of burnt lime and dolomite lime produced in German lime works. Additional relevant lime kilns, in addition to the lime-burning facilities covered by this chapter, have been identified in the iron and steel industry and sugar industry sectors. Those facilities are covered not in the present chapter, but in the sections for the relevant categories, 2.C.1 (Chapter 4.4.1) and 2.H.2 (Chapter 4.9.2). Information on other limestone-using sectors is provided in Chapter 4.2.7 (CRF 2.A.4d).

Because of the wide range of applications covered by the sector's products, lime production is normally more insulated from economic fluctuations than is production of other mineral products, such as cement. Production of burnt lime is only slightly below the level seen in recent years. Dolomite-lime production, on the other hand, has decreased more sharply.

Table 137: Production and CO_2 emissions in the German lime industry

Year	Lime		Dolomite lime	
	Production [t]	CO_2 emissions [Millions of t]	Production [t]	CO_2 emissions [Millions of t]
1990	7,323,657	5.463	603,427	0.523
1991	6,474,897	4.830	605,186	0.525
1992	6,563,031	4.896	587,474	0.509
1993	6,852,841	5.112	526,799	0.457
1994	7,512,403	5.604	516,115	0.447
1995	7,611,109	5.678	555,927	0.482
1996	7,019,060	5.236	556,487	0.482
1997	7,114,649	5.308	541,893	0.470
1998	6,799,487	5.072	569,540	0.494
1999	6,814,898	5.084	490,745	0.425
2000	6,993,608	5.217	536,032	0.465
2001	6,665,136	4.972	522,778	0.453
2002	6,591,281	4.917	526,596	0.457
2003	6,731,929	5.022	445,625	0.386
2004	6,692,954	4.993	468,873	0.407
2005	6,535,470	4.875	473,632	0.411
2006	6,646,233	4.958	471,784	0.409
2007	6,873,539	5.128	468,593	0.406
2008	6,868,481	5.124	464,167	0.402
2009	5,500,965	4.104	341,713	0.296
2010	6,124,382	4.569	341,779	0.296
2011	6,330,677	4.723	350,482	0.304
2012	6,035,949	4.503	241,833	0.210
2013	6,195,672	4.622	218,375	0.189

Because the applicable emission factor in this category is constant, CO_2 emissions and lime / dolomite-lime production depend linearly on each other; as a result, the above statements apply to CO_2 emissions mutatis mutandis.

4.2.2.2 Methodological issues (2.A.2)

In burning of limestone and dolomite, CO_2 is released, and it reaches the atmosphere via the exhaust gas of the process. The pertinent emissions level is obtained by multiplying the amount of product in question (lime or dolomite lime) and the relevant emission factor.

Emission factors

The pertinent CO_2 emissions are calculated with the following factors:

EF_{lime} 0.746 t CO_2/t lime (stoichiometric 0.785 * oxide fraction 0.95)
$EF_{dolomite\ lime}$ 0.867 t CO_2/t dolomite lime (stoichiometric 0.913 * oxide fraction 0.95)

The emission factors used are based on the stoichiometric factors, as well as on the assumption that 95 % of the burnt lime consists of CaO, that 95 % of the dolomite lime consists of CaO • MgO and thus that 5 % of the total mass consists of impurities that are not CO_2-relevant. This approach is in keeping with the Tier 1 approach of the *IPCC Guidelines 2006* (IPCC 2006, Chapter 2.3.1.2, Table 2.4).

Activity data

The German Lime Association (BVK) collects the production data for the entire time series, on a plant-specific basis, and makes them available for reporting purposes. The quantities produced by plants that are not included in the German Lime Association's association statistics are estimated on the basis of existing information (such as operator figures, and data published in the framework of emissions trading) and then added to the German Lime Association's figures. This ensures that all of German lime production is taken into account. Ever since the relevant method was changed to conform with the 2006 IPCC Guidelines, it is also being assumed that, in all years of the period covered by the report, as of the year 1990, 2 % of the burnt lime is being separated out as dust, via suitable waste-gas-scrubbing systems, and is not being returned to the production process. This is taken into account via a fictive 2 % increase in the pertinent activity data.

The manner in which the activity data are determined conforms with the Tier 2 approach of the *IPCC Guidelines 2006* (IPCC 2006, Chapter 2.3.1.1, equation 2.6).

4.2.2.3 Uncertainties and time-series consistency (2.A.2)

The EU monitoring guidelines for emissions trading call for activity data to have an accuracy of 2.5 %. Since a) the German Lime Association's (BV Kalk's) lime-production data are based on operators' figures as provided in the framework of CO_2-emissions trading, b) those data have been obtained via two separate, parallel channels and thus are quality-assured, and c) the plants not included in the association's statistics (and thus assessed after the fact) represent only a small share of the total number of plants concerned, the **uncertainties** for the **activity data** used are estimated to be 2.5 % and +2.5 %. These figures apply to both burnt lime and dolomite lime.

The uncertainties for the emission factors used for burnt lime were estimated to be -11 % and +5 %. The uncertainties for the emission factors used for dolomite lime were estimated to be -30 % and +2 %.

4.2.2.4 Category-specific quality assurance / control and verification (2.A.2)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The quality of the production-quantity data collected by the German Lime Association (BV Kalk) is assured via internal controls of the association, carried out with the help of separate surveys in the sector's technical and commercial areas (Tier 2).

The comparison with the available information from the ETS yielded discrepancies that can be explained as the result of differences in methods: on the one hand, as differences between the specifications in the ETS and on the part of the IPCC, and, on the other, as the result of methodological changes made between ETS trading periods.

The IPCC default factors used are suitable for the country-specific method.

4.2.2.5 Category-specific recalculations (2.A.2)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.2.2.6 Planned improvements (category-specific) (2.A.2)

No category-specific improvements are planned.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.2.3 Mineral products: Glass production (2.A.3)

KC	Category	Activity		1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013	1990 (kt CO_2-e.)
-/-	2.A.3 Mineral Products: Glass Production	Production of various types of glass	CO_2	780.5	(0.06%)	875.4	(0.09%)	12.2%	

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	AS	CS
NO_X, NMVOC, SO_2	Tier 2	AS	CS

The category *Mineral products*: *Glass production* is not a key category.

4.2.3.1 Source-category description (2.A.3 Glass production)

Germany's glass industry produces a wide range of different glass types with different chemical compositions. Germany's glass sector comprises the following sub-sectors: container glass, flat glass, domestic glass, special glass and mineral fibres (glass and stone wool). The sub-sectors with the highest production shares are container glass (accounting for about half of total glass production) and flat glass (about one-fourth of total glass production) (BV Glas, 2014a). The inventory calculations do not include the category "water-glass production". All relevant soda-ash quantities for water-glass production are taken into account in 2.A.4.b (Chapter 4.3.7).

In production, homogeneous glass mixtures combining primary and secondary raw materials are melted down at temperatures between 1,450 °C and 1,650 °C. The process-related CO_2 emissions under consideration here are released from the raw-material carbonates during the melting process in the furnace. CO_2 emissions – in small amounts – also occur in neutralisation of HF, HCl and SO_2 in exhaust gases, with the help of limestone or other carbonates. Because the amounts involved are so small, these emissions are not considered here.

The following table shows the trends, since 1990, in activity data, process-related CO_2 emissions and the implied emission factors resulting for all glass types overall.

Table 138: Activity data and process-related CO_2 emissions since 1990; IEF covering all glass types

Year	Activity data [t]	Process-related CO_2 emissions [t]	IEF for all glass types [t CO_2/ t $_{glass}$]
1990	6,561,849	780,480	0.119
1991	7,202,807	821,376	0.114
1992	7,228,752	810,610	0.112
1993	7,074,837	778,104	0.110
1994	7,760,000	747,225	0.096
1995	7,621,300	881,306	0.116
1996	7,519,600	853,395	0.113
1997	7,392,000	833,771	0.113
1998	7,314,000	803,411	0.110
1999	7,442,239	822,236	0.110
2000	7,505,000	846,300	0.113
2001	7,293,000	846,289	0.116
2002	7,084,000	800,501	0.113
2003	7,205,720	788,726	0.109
2004	7,088,900	791,150	0.112
2005	6,948,400	802,746	0.116
2006	7,285,600	842,228	0.116
2007	7,535,300	829,060	0.110
2008	7,513,900	824,868	0.110
2009	6,784,100	745,664	0.110
2010	7,163,600	828,828	0.116
2011	7,341,600	835,138	0.114
2012	7,079,700	823,341	0.116
2013	7,406,600	875,408	0.118

It is clear that emissions tend to follow the trend in activity data. At the same time, the implied emission factors indicate that the correlation is not rigid; some discrepancies do occur. The discrepancies are due to annual fluctuations in production quantities of various individual glass types, and in cullet inputs. They are thus logical and calculatorily correct.

4.2.3.2 Methodological issues (2.A.3 Glass production)

The CO_2 emissions (the main pollutant) are calculated via a Tier 2 method, because the detailed activity data are tied to specific emission factors (that are in keeping with the relevant carbonate concentrations). The following carbonates are taken into account as the main sources of CO_2 formation during the melting process: Calcium carbonate ($CaCO_3$), soda ash / sodium carbonate (Na_2CO_3), magnesium carbonate ($MgCO_3$) and barium carbonate ($BaCO_3$). In the present context, the CO_2 emissions from all carbonates are reported as a sum; inputs of raw-materials – soda ash – are considered under 2.A.4.b (cf. 4.2.5). Here, it should be noted that the calculated soda-ash-input quantities cannot be published, because data on soda ash production (cf. 4.2.5.2) are subject to statistical confidentiality and must not be derivable from balance sheets.

The production figures (**activity data**) are taken from the regularly appearing annual reports of the Federal Association of the German Glass Industry (Bundesverband Glasindustrie; BV Glas, 2014a). "Production" refers to the amount of glass produced, which is considered to be equivalent to the amount of glass melted down. It must be remembered that a fraction of the molten glass, corresponding to the quantity of internal cullet, is not included in production statistics (see also the remarks below regarding cullet inputs). As a result, the figures given in the statistics correspond not to the actual quantities of molten glass involved, but to the molten-glass quantities consisting of primary raw materials and external cullet. Further processing and treatment of glass and glass objects are not considered.

The following activity data were determined for 2013:

Table 139: Glass: Activity data for the various industry sectors (types of glass)

Industry sector	Activity data for 2013 [t]
Container glass	3,993,600
Flat glass	1,981,000
Glass fibre and wool	343,800
Special glass	321,600
Stone wool	606,500
Domestic glass	160,100

Source: BV Glas, 2014

The following sector-specific cullet percentages are assumed:

Table 140: Cullet percentages for the various types of glass

Industry sector	Cullet percentage □[%] in the input raw material
Container glass	59 – 65 (annually varying)
Flat glass	10 (entire time series)
Domestic glass	5 (entire time series)
Special glass	5 (entire time series)
Glass fibre and wool	40 (entire time series)
Stone wool	40 (entire time series)

Source: HVG, 2008, and surveys of the Federal Association of the German Glass Industry (BV Glas) (2014b)

The cullet percentage for container glass is known only for the western German Länder as of 1990. For Germany as a whole, it is known for the period since 1995. No data are available for the new German Länder for the period from 1990 to 1994. For that reason, an average cullet percentage input was estimated on the basis of the various glass sectors' average percentages of total glass production. In 2007, the firm of Gesellschaft für Glasrecycling und Abfallvermeidung mbH (GGA) was forced to cease operations, under cartel law. As a result, no reliable cullet-input data have been available from that source since 2007. Since 2012, the Federal Association of the German Glass Industry (BV Glas) has provided data, from association surveys, on cullet inputs in the container-glass industry for the period as of 2007 (BV Glas, 2014b). The various sectors' cullet fractions contain only external cullet, since internal cullet is not included in production statistics, which are the basis for the relevant activity data. The total cullet fraction in vats can be considerably larger when internal cullet is involved.

Since the exhaust gases occurring during the melting process are drawn off together with combustion-related exhaust gases – i.e. as a collective exhaust-gas stream – measurements cannot be used to determine the CO_2 quantities produced by the German glass industry. For this reason, a calculation procedure is used that is based on the weight shares for the aforementioned carbonates and on cullet input in the container-glass and flat-glass industry. Figures on the chemical composition of the various types of glass produced in Germany have been taken from VDI-Richtlinie (guideline) 2578 (VDI, 1999) and from the ATV-DVWK Merkblatt (standards sheet of the German Association for Water, Wastewater and Waste) 374 (ATV, 2004).

The procedure used to determine **emission factors** for the various glass oxides involved and the pertinent emissions is described in detail in the 2007 NIR (Chapter 4.1.7.2, p. 251ff).

The following emission factors were calculated for the various industry sectors. The factors vary annually in keeping with variations in cullet inputs (ranges are given for container glass):

Table 141: CO_2-emission factors for various glass types (calculated in comparison with figures from the CORINAIR manual)

Glass type	Calculated emission factor [kg CO_2/ t $_{molten\ glass}$] - stoichiometric / incl. cullet input-			Default emission factors [kg CO_2/ t $_{molten\ glass}$] - pursuant to CORINAIR -		
Container glass	193	/	49 – 86*	171	-	229
Flat glass	208	/	187		210	
Domestic glass	120	/	114		-	
Special glass	113	/	107	0	-	178
Glass fibre	198	/	119	0	-	470
Stone wool	299	/	179	238	-	527
Unspecified	174	/	139		-	

* Most recently, 76 kg CO_2 per t of molten glass

4.2.3.3 Uncertainties and time-series consistency (2.A.3 Glass production)

The production data have been taken from the internal statistics of the Federal Association of the German Glass Industry (BV Glas). Since that association represents nearly all of Germany's container-glass and flat-glass manufacturers, the sectoral data it provides are highly accurate. An uncertainty of 5 % was thus assumed. The association's representation of all other glass sectors is incomplete, and thus the association cannot guarantee the completeness of the data for such other sectors. For this reason, an uncertainty of 10 % was assumed for those areas. Until about 2002, BV Glas also cross-checked the data against data of the *Federal Statistical Office*.

The uncertainty in the cullet figures for container glass lies within the customary range for statistical determinations. For the new German Länder, an uncertainty of 20 % has been assumed, because no statistical survey has been carried out; only an estimate is available. Use of data from the association's own internal surveys, relative to cullet use as of 2007, increases the uncertainties. For example, surveys take account only of production sites' internal cullet and external container-glass cullet, and do not cover any quantities of flat glass that may be used in container-glass production.

The figures on cullet use for all other glass types are considerably less precise, however, since only estimates are available for those areas. An uncertainty of 20 % was thus assumed.

For the CO_2 emission factors, an uncertainty of 14 % is used in the case of container glass, and a figure of 22 % is used for all other types of glass.

4.2.3.4 Category-specific quality assurance / control and verification (2.A.3 Glass production)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The calculated emission factors were compared with several different sources, including the CORINAIR manual and the "Baden-Württemberg 2004 emissions declaration" ("Emissionserklärung 2004 Baden-Württemberg"; UMEG 2004). According to that comparison, the calculated emission factors may be considered accurate. In addition, the IEF was compared with those of the following countries, which also consider soda ash use only as an integrated part of glass production, i.e. do not consider such use separately: Austria (0.10), Italy (0.11) and the Netherlands (0.13). These values are comparable to the German IEF for the glass industry (which fluctuates around 0.1).

The information provided regarding the chemical composition of the various glass types continues to be considered correct in the present context. The applicable rate of cullet input, for which the data still need to be improved (cf. Chapter 4.2.3.3), has considerable influence in this regard.

4.2.3.5 Category-specific recalculations (2.A.3 Glass production)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.2.3.6 Planned improvements (category-specific) (2.A.3 Glass production)

No further improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.2.4 Mineral products: Ceramics (2.A.4.a)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/-	2.A.4 Mineral Products: Other process uses of carbonates		CO_2	867.2	(0.07%)	568.1	(0.06%)	-34.5%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1	NS	CS
NO_X, NMVOC, SO_2	Tier 1	NS	CS

The overarching category 2.A.4 – *Mineral products: Other uses of carbonates* is not a key category.

4.2.4.1 Source-category description (2.A.4 Ceramics)

The process-related emissions determined for the ceramics industry originate in the following sub-category elements:

1. "Production of ceramic products": This time series shows the quantity produced by the entire ceramics industry in Germany. The non-CO_2 emissions for the entire ceramics industry are calculated via these activity data. Process-related CO_2 emissions, on the other hand, are calculated only for the sub-quantities "roof tiles" and " masonry bricks" (see below).
2. "Brick production" (CO_2); "roof tile" product: Production of roof tiles is a subset of the aforementioned activity data for the entire ceramics industry. It is used only for calculation of process-related CO_2 emissions (with consideration of the applicable proportions for limestone and for organic impurities).
3. "Brick production" (CO_2); "masonry brick" product: Production of masonry bricks is also a subset of the aforementioned activity data for the entire ceramics industry. This production figure is also used only for calculation of process-related CO_2 emissions (with

consideration of porosity agents, as well as of the applicable proportions for limestone and for organic impurities in the pertinent raw materials).

Table 142: Activity data and process-related CO_2 emissions in the ceramics industry (CRF 2.A.4.a)(rounded, and thus possibly with discrepancies between individual figures and the total)

	Ceramics products			Process-related CO_2 emissions		
	Total	of which, masonry bricks	of which, roof tiles	Masonry bricks	Roof tiles	Total
	[kt]					
1990	21595	16524	1758	481	50	531
1991	20772	15691	1946	457	56	512
1992	22769	17302	2216	503	63	567
1993	24534	18827	2349	548	67	615
1994	30458	23925	2611	696	75	771
1995	24730	18827	2466	548	71	618
1996	22663	16965	2598	494	74	568
1997	22939	17298	2521	503	72	575
1998	22798	17048	2658	496	76	572
1999	22395	16591	2849	483	81	564
2000	21199	15383	2924	448	84	531
2001	18003	12771	2642	372	76	447
2002	16500	11686	2381	340	68	408
2003	16443	11631	2383	338	68	407
2004	16796	11697	2601	340	74	415
2005	14643	9881	2485	288	71	359
2006	16019	10883	2648	316	76	392
2007	16035	10885	2618	317	75	392
2008	13867	9302	2254	271	64	335
2009	11505	7909	1919	227	55	282
2010	12653	8463	2179	246	62	308
2011	13860	9377	2286	273	65	338
2012	13409	9233	2118	269	61	330
2013	13247	9281	1962	270	56	326

4.2.4.2 Methodological issues (2.A.4.a Ceramics)

The IPCC Guidelines for National Greenhouse Gas Inventories 2006 contain remarks on calculation of process-related CO_2 emissions for the ceramics industry (IPCC 2006d, Chapter 2.5.1 "Ceramics"). In general, the following product groups are normally allocated to this industrial production sector: roof tiles and masonry bricks, stoneware pipes, refractory products, expanded clay, wall and floor tiles, household ceramics, sanitary ceramics, technical ceramics, inorganic bonded abrasives. For purposes of the national inventory, only estimates relative to production of roof tiles and masonry bricks have been carried out to date. This results from the important quantities of such products that are produced, and from the limited availability of data for the sector.

The CO_2 emissions in these sub-areas are calculated via a Tier 1 method, because no detailed data are available and because this category is not a key category.

Activity data

Official statistics are of limited use in determining actual production trends in the brick and tile industry, in terms of weights, since such statistics list masonry-brick production in cubic metres and roof tiles in numbers of tiles. Produced weight quantities can be determined only via conversion factors. The conversion factors used for masonry bricks and roof tiles consist of values obtained by the Bundesverband der Deutschen Ziegelindustrie (association of the German brick and tile industry) from experience.

Emission factors

Process-related CO_2 emissions originate in the raw materials for production of roof tiles and masonry bricks (normally, locally available loams and clays with varying concentrations of $CaCO_3$ (limestone) and, in some cases, with organic impurities). On the basis of information from the association of the German brick and tile industry (Bundesverband der deutschen Ziegelindustrie), an emission factor of 28.6 kg / $t_{product}$ is assumed for process-related CO_2 emissions from $CaCO_3$ and organic impurities in raw materials. That figure corresponds to a mean $CaCO_3$ fraction of 65 kg/t in the raw meal.

Porous masonry bricks account for about half of all masonry bricks produced in Germany. They are produced by adding organic porosity agents to the raw materials. When the bricks are fired, these agents burn, creating hollows. Most of the porosity agents used are renewable resources (such as sludges from the paper industry, and spent liquors from pulp production). Non-renewable substances (especially polystyrene) are also used, however. The resulting CO_2 emissions are minimal by comparison to those from the limestone fractions in the raw materials. Nonetheless, they are taken into account in the inventory via a slightly higher CO_2-emission factor for masonry bricks (29.1 kg CO_2/t masonry bricks, as opposed to 28.6 kg CO_2/t for roof tiles).

The determined activity data and resulting CO_2 emissions are shown in Table 142. The process-related CO_2 emissions for this sub - category, at considerably less than one million tonnes of carbon dioxide, are not particularly important.

4.2.4.3 Uncertainties and time-series consistency (2.A.4.a Ceramics)

Due to the need for conversion of area and volume figures into produced quantities, the uncertainty for the three sets of activity data is estimated at +/- 20 %; no other uncertainty factors are relevant.

The uncertainties for the **CO_2-emission factors** used for production of masonry bricks and roof tiles are determined primarily by the uncertainty relative to the $CaCO_3$ quantities contained in the raw materials (+/- 30 %).

The time series are consistent for activity data for production of masonry bricks and roof tiles, and the related CO_2-emission factors are consistent as well. Some changes have occurred, throughout the time series, in availability of statistics for various product types. These changes accounted for only about 1 % of the amounts of bricks produced, and for less than 0.5 % of total ceramics production, however.

The **activity data** for total ceramics production contain a methodological discontinuity that results from a substantial change in the available statistical data. For masonry bricks and roof tiles, figures in thousands of t were available until 1994. As of 1995, the figures are only in thousands of m^3 or thousands of units (piece count). In the 2007 NIR, the relevant impacts are discussed in detail. On the other hand, the methods discontinuity is irrelevant with regard to CO_2 emissions.

4.2.4.4 Category-specific quality assurance / control and verification (2.A.4.a Ceramics)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The data from greenhouse-gas-emissions trading cannot be compared directly with relevant emissions data from the National Inventory. The reason for this is that, in emissions trading, installations (plants) are included and grouped in accordance with threshold values, and thus data are available for only part of the ceramics industry – and only for some brick and roof-tile producers.

4.2.4.5 Category-specific recalculations (2.A.4.a Ceramics)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.2.4.6 Planned improvements (category-specific) (2.A.4.a Ceramics)

No category-specific improvements are planned.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.2.5 Non-metallic minerals industry: other soda ash use (2.A.4.b)

4.2.5.1 Category description (2.A.4.b)

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1	NS	D

The overarching category 2.A.4 – *Mineral products: Other uses of carbonates* is not a key category.

Soda ash is used in a wide range of industrial applications. The most important areas of use include the glass industry, production of detergents and cleansers and the chemical industry. It is assumed that the carbon contained in soda ash is released sooner or later, regardless of the use involved, into the air as CO_2.

Emissions resulting solely from use of soda ash correlate in a fixed way to the pertinent calculated quantities used – in this context, outside of the glass industry (cf. the methodological issues in the following chapter):

Table 143: Activity data and use-related CO_2 emissions outside of the glass industry, since 1990

Year	Activity data [t]	CO_2 emissions [kt]
1990	809,885	336.1
1991	587,756	243.9
1992	402,053	166.9
1993	379,687	157.6
1994	429,884	178.4
1995	340,793	141.4
1996	336,440	139.6
1997	387,823	160.9
1998	452,848	187.9
1999	394,164	163.6
2000	411,281	170.7
2001	490,469	203.5
2002	437,769	181.7
2003	529,515	219.7
2004	500,956	207.9
2005	517,159	214.6
2006	484,871	201.2
2007	550,966	228.7
2008	538,477	223.5
2009	457,076	189.7
2010	528,885	219.5
2011	587,144	243.7
2012	516,444	214.3
2013	582,950	241.9

Source: Calculations of the Federal Environment Agency (UBA); for pertinent derivation, cf. the following chapter

4.2.5.2 Methodological issues (2.A.4.b)

Activity data

Since the 2010 inventory review, those soda ash inputs are determined that are not taken into account, for emissions calculations, in other categories. The relevant calculations are oriented to the greatest possible emissions from the applicable soda ash use. The total quantity of soda ash used in Germany is determined via balancing (quantity produced plus imports and less exports) (a). The relevant import and export quantities are taken from the foreign-trade statistics of the Federal Statistical Office (STATISTISCHES BUNDESAMT, 2014). Emissions from soda ash use in the glass industry are already taken into account, source-specifically, under category 2.A.3 (b). The soda ash quantities used in that category are deducted from the soda ash use of relevance in the present section. The activity data in the above table (c) have been obtained in accordance with the following formula:

c = a minus b

Emission factor

Stoichiometrically, the emission factor for soda ash use is 415 kg CO_2 per tonne of soda ash, under the assumption that release is complete (a conservative approach).

4.2.5.3 Uncertainties and time-series consistency (2.A.4.b)

Activity data

The calculations of the relevant quantities of soda ash used exhibit large uncertainties (maximally, -18%/+18%), as a result of statistical fluctuations and of the calculatory assumptions on which the above derivation is based.

Emission factor

The emission factor for soda ash use is subject to small, explained uncertainties in the area of product purity and the completeness of the chemical transformations involved (-5%/+0%).

4.2.5.4 Category-specific QA/QC and verification (2.A.4.b)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

Due to a lack of assigned expert resources, it was not possible to have category experts carry out QA/QC for the area "use of soda ash / sodium carbonate". Quality assurance was carried out by the Single National Entity. Data were taken from previous years or determined on the basis of existing calculation routines.

It is not possible at present to verify quantitatively the input quantities of soda ash that cannot be allocated to the glass industry. The pertinent estimates are conservative, however; they do not underestimate the quantities of relevance for the inventory. Qualitatively, the pertinent calculation results do not contradict the sales figures of soda-ash producers obtained on a sample basis.

The stoichiometric emission factor is in keeping with the default figures given in the IPCC-Guidelines (IPCC, 2006d, Ch. 2, table 2.1)

4.2.5.5 Category-specific recalculations (2.A.4.b)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.2.5.6 Category-specific planned improvements (2.A.4.b)

No further improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.2.6 Production of non-metallurgical magnesium products (2.A.4.c new)

4.2.6.1 Category description (2.A.4.c)

The greenhouse-gas emissions from this category amount to less than 0.05 % of the total inventory (not including LULUCF), and they are less than 500 kt CO_2-equivalents. What is more, relevant annual surveys cannot be assured (pursuant to FCCC/SBSTA/2013/L.29/Add.1, para 37). For this reason, we refrain from reporting on this area (IPCC, 2006d). The present chapter thus presents a one-time quantitative estimation of the emissions that are not covered by the inventory as a result. In addition, a compilation of all sources listed as "not estimated" is presented in Annex 5 in Chapter 21 of the present report.

4.2.6.2 Methodological issues (2.A.4.c)

It was not possible to identify any suitable activity data for this category segment in the official statistics. Some product types, such as refractory bricks, are already included in the activity data for the ceramics industry (CRF 2.A.4.a, Chapter 4.2.4). The additionally identified category "production of other carbonates" is a collective in which magnesium carbonates are a non-quantifiable sub-quantity. The resulting time series shows only production quantities less than 300,000 t. The lowest threshold for inclusion would be about one million tonnes of a product with large fractions of CaO and MgO. That production threshold is not achieved with any relevant product type. This also applies to the product types already included in other categories.

Because the pertinent statistics contain collective categories, the potential CO_2 emissions cannot be precisely calculated. They are estimated to be considerably less than 100,000 t of carbon dioxide.

4.2.6.3 Uncertainties and time-series consistency (2.A.4.c)

No conclusions relative to uncertainties and time-series consistency can be drawn.

4.2.6.4 Category-specific QA/QC and verification (2.A.4.c)

Due to resources limitations, and to the area's minimal relevance, no QC/QA has been carried out for reporting in this area.

An initial relevant estimate was made in the framework of a research project. It was then reviewed by the specialised contact person within the Federal Environment Agency (UBA) and confirmed in the above-described manner.

4.2.6.5 Category-specific recalculations (2.A.4.c)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.2.6.6 Category-specific planned improvements (2.A.4.c)

No further activities are planned.

4.2.7 Non-metallic minerals industry: other limestone and dolomite use (2.A.4.d)

4.2.7.1 Category description (2.A.4.d)

This category's emissions are not reported separately; instead, they are reported in the sections for the categories that use limestone and dolomite (they are thus included elsewhere – IE). In the relevant categories, they are also taken into account in key-category analysis.

For the sake of simplicity, reference will be made solely to "limestone" (except in special cases requiring explanation), even where both limestone and dolomite, and other carbonates, are subsumed.

Until the 2014 Submission, and in supplementation to the requirements set forth in the 1996 IPCC Guidelines, in this category all production and use of limestone and dolomite were considered in balance form, and the results were compared with the inventory categories. This "limestone balance" appeared most recently in the 2014 NIR.

No findings are available regarding use of limestone in emissions-relevant sectors other than the categories listed below.

4.2.7.2 Methodological issues (2.A.4.d)

The following section provides an overview of national limestone inputs (category references). Emissions calculations are carried out for those categories in which CO_2 emissions are produced via limestone use:

- 1.A.1.a Flue-gas desulphurisation in power stations (limestone inputs)
- 2.A.1 Cement-clinker production (limestone fraction in the relevant raw materials)
- 2.A.2 Limestone production (limestone inputs)
- 2.A.3 Glass production (limestone fraction in the relevant raw materials)
- 2.A.4.a Ceramic-brick production (limestone fraction in the relevant raw materials)
- 2.C.1 Iron and steel production (limestone inputs and lime kilns)
- 2.H.2 Lime kilns in sugar production (limestone inputs)
- 3.G Soil liming in agriculture and forestry

The pertinent data are updated in the relevant categories (cf. the above list). In addition, pertinent methodological aspects are explained in the relevant category chapters (cf. chapters 19.1.2, 4.2.1, 4.2.2, 4.2.7, 4.4.1, 4.9.2 and 5.8). The findings and quantitative surveys relative to limestone inputs in lime kilns of the iron and steel industry, and of the sugar production sector, are worthy of special mention.

4.2.7.3 Uncertainties and time-series consistency (2.A.4.d)

Information regarding uncertainties for activity data and emission factors for the relevant limestone uses is provided in the relevant category chapters.

4.2.7.4 Category-specific QA/QC and verification (2.A.4.d)

General quality control and quality assurance, in keeping with the requirements of the QSE manual and its associated documents, have been carried out in those categories into which category 2.A.4.d leads.

The activity data and the emission factors for the relevant limestone uses are verified and updated in the relevant categories.

4.2.7.5 Category-specific recalculations (2.A.4.d)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.2.7.6 Category-specific planned improvements (2.A.4.d)

No improvements, and no annual updating of the limestone balance sheet, are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.3 Chemical industry (2.B)

Category 2.B is divided into the sub-categories 2.B.1 through 2.B.10. These include ammonia production (2.B.1), nitric acid production (2.B.2), adipic acid production (2.B.3), caprolactam, glyoxal and glyoxylic acid production, (2.B.4), carbide production (2.B.5), titanium dioxide production (2.B.6), soda ash production (2.B.7), petrochemical and carbon black production (2.B.8) and production of fluorinated chemicals (2.B.9).

In the category *Other* (2.B.10), only precursor substances from production of fertilisers and sulphuric acid are reported. Production of dodecanedioic acid is described in 2.B.10, while process-related N_2O emissions are reported under 2.G.3, for reasons of confidentiality.

4.3.1 Chemical industry: Ammonia production (2.B.1)

4.3.1.1 Category description (2.B.1)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T	**2.B.1 Chemical Industry**	**Ammonia production**	**CO_2**	**6,025.0**	**(0.49%)**	**6,739.0**	**(0.72%)**	**11.9%**

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 3	PS	PS
NO_X			D

The category *Chemical industry*: *ammonia production* is a key category for CO_2 emissions in terms of emissions level and trend.

Ammonia is produced on the basis of hydrogen and nitrogen, using the Haber-Bosch process, which also forms CO_2. Hydrogen is produced from synthetic gas (usually) based on natural gas, via a highly integrated process, *steam reforming*, while nitrogen is produced via air dissociation.

The various plant types for the production of ammonia cannot be divided into individual units and be compared as independent process parts, due to the highly integrated character of the procedure. In *steam reforming*, the following processes are distinguished:

- ACP – *advanced conventional process* with a fired primary reformer and secondary reforming with excess air (stoichiometric H/N ratio)
- RPR – *reduced primary reformer process*, carried out under mild conditions in a fired primary reformer, and with secondary splitting with excess air (sub-stoichiometric H/N ratio)
- HPR – *heat exchange primary reformer process* – autothermic splitting with heat exchange using a steam reformer heated with process gas (heat exchange reformer) and a separate secondary reformer or a combined autothermic reformer using excess air or enriched air (sub-stoichiometric or stoichiometric H/N ratio).

The following procedure is also used:

- Partial oxidation – gasification of fractions of heavy mineral oil or vacuum residues in production of synthetic gas.

Ammonia is produced at five locations in Germany. The production operations use both the steam-reforming and partial-oxidation processes.

The production decrease of more than 15 % (corresponding to an amount of nearly 300 kt) in the first year after German reunification was the result of a market shake-up, over 2/3 of which was borne by the new German Länder. The production level then remained nearly constant in the succeeding years until 1994. It has not been possible to determine the reason for the renewed growth as of 1995, which returned production to the level seen in 1990. However, the growth could be due to resumption of production processes in the new German Länder, following extensive modernisations. Since 1995, production levels have fluctuated only slightly. The nearly 8% production decrease that occurred in 2009 was due to the global economic crisis. The IEF is higher than those of other countries, since heavy fuel oil is used in Germany, in addition to natural gas. Heavy fuel oil produces significantly higher CO_2 emissions than natural gas does.

4.3.1.2 Methodological issues (2.B.1)

In keeping with this category's categorisation as a key category for CO_2 emissions, as of the 2010 report, emissions data for this category are being collected and reported in accordance with the Tier 3 standard. This is being carried out on the basis of a co-operation agreement with the relevant plant operators for delivery of plant-specific data.

The operators transmit their plant-specific data to the Industrieverband Agrar (IVA) agrochemical industry association. That association anomymises the data, for reasons of confidentiality, and then transmits it, in plant-specific form, to the Federal Environment Agency (UBA). The Federal Environment Agency carries out quality assurance and then aggregates the data.

The plant operators report:

- the ammonia quantities produced (**activity data**),
- the quantities of raw materials used in the process (natural gas, heavy mineral oil), less the pertinent fuel quantities used for energy purposes and so reported in the Energy Balance (TFR_i),
- the raw materials' carbon content factor (CCF_i) and carbon oxidization factor (COF_i),
- the quantity of CO_2 that undergoes further processing (R_{CO2}), and the purpose for which it is used.

CO_2 emissions:

The CO_2 emissions

are calculated in keeping with Equation 3.3 in the 2006 IPPC Guidelines:

$$E_{CO2} = \sum (TFR_i * CCF_i * COF_i * 44/12 - R_{CO2})$$

The recovered quantity of CO_2 that is used in other production processes – such as urea production – (and is reported in connection with those other processes) is not included in the non-reported emissions.

The carbon content in natural gas and heavy fuel oil is determined by the five producers in the following manner: One producer uses a standard factor that has been obtained via ongoing operational analysis (C content = 86.1 % by weight). A second producer uses the IPCC default value for natural gas. For the other gases – the gas mixtures used – that producer determines the applicable C content levels analytically, on the basis of the C content levels of the individual gases contained and their quantity shares of the mixtures. In two cases, producers use the data provided by the relevant natural gas suppliers. And one producer calculates emissions with the help of weighted monthly averages obtained on the basis of his own analyses.

Emission factor for NO_x:

For the NO_X emission factor, the default emission factor given in the *CORINAIR Guidebook*, 1 kg/t NH_3, is used (EMEP EEA Emission Inventory Guidebook, TFEIP-endorsed draft, May 2009).

4.3.1.3 Uncertainties and time-series consistency (2.B.1)

Using a procedure in keeping with equation 6.3 in IPCC GPGAUM, the IVA aggregates the uncertainties reported by the operators and communicates the result to the Federal Environment Agency.

The uncertainty for the activity data is ± 0.6 %. The uncertainty for the emissions is ± 1 %.

4.3.1.4 Category-specific quality assurance / control and verification (2.B.1)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

4.3.1.5 Category-specific recalculations (2.B.1)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.3.1.6 Planned improvements (category-specific) (2.B.1)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.3.2 Chemical industry: Nitric acid production (2.B.2)

4.3.2.1 Category description (2.B.2)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T	2.B.2 Chemical Industry	Nitric acid production	N_2O	3,258.5	(0.27%)	480.4	(0.05%)	-85.3%

Gas	Angewandte Methode	Quelle der Aktivitätsdaten	genutzte Emissionsfaktoren
N_2O	Tier 3	PS	PS

The category *Chemical industry*: *Nitric acid production* is a key category for N_2O emissions in terms of emissions level and trend.

In production of nitric acid, nitrous oxide occurs in a secondary reaction. In Germany, there are currently eight nitric acid production plants.

HNO_3 production occurs in two process stages:

- **Oxidation** of NH_3 to NO and
- **Conversion of** NO to NO_2 and **absorption** in H_2O.

Details of the process are outlined below:

Catalytic oxidation of ammonia

A mixture of ammonia and air at a ratio of 1:9 is oxidised, in the presence of a platinum catalyst alloyed with rhodium and/or palladium, at a temperature of between 800 and 950 °C. The relevant reaction, according to the Ostwald process, is as follows:

$$4\,NH_3 + 5\,O_2 \rightarrow 4\,NO + 6\,H_2O$$

Simultaneously, nitrogen, nitrous oxide and water are formed by the following undesired secondary reactions:

$$4\,NH_3 + 3\,O_2 \rightarrow 2\,N_2 + 6\,H_2O$$

$$\mathbf{4\,NH_3 + 4\,O_2 \rightarrow 2\,N_2O + 6\,H_2O}$$

All three oxidation reactions are exothermic. Heat may be recovered to produce steam for the process and for export to other plants and/or to preheat the residual gas. The reaction water is condensed in a cooling condenser, during the cooling of the reaction gases, and is then conveyed into the absorption column.

4.3.2.2 Methodological issues (2.B.2)

In keeping with the 2006 IPCC Guidelines, nitric-acid production is now reported plant-specifically, in accordance with the Tier 3 standard. This is being carried out on the basis of a co-operation agreement with the relevant plant operators for delivery of plant-specific data. Through the 2014 reporting round, six operators sent data to the Industrieverband Agrar (IVA) industrial association. After carrying out quality assurance, the IVA aggregated the data, to protect confidentiality, and then transmitted the so-aggregated data to the Federal Environment Agency (AD and EF). One company sent its data (AD, EF, N_2O emissions and information about any reduction equipment used) directly to the Federal Environment Agency. After carrying out quality assurance, the Federal Environment Agency then aggregated that company's data with the data provided by the IVA and entered the resulting so-aggregated data into the CSE emissions database.

The relevant cooperation agreement was adapted for the new commitment period and in keeping with the new 2006 IPCC Guidelines. The Federal Environment Agency now receives the plant-specific data for the six plants, in anonymised form, via IVA. The seventh operator continues to transmit his data directly to the Federal Environment Agency.

The plant operators report:

- the quantities of nitric acid produced (**activity data**);
- the EF;
- the N_2O emissions measured in the raw gas;
- where emissions-reduction equipment is used, the N_2O emissions measured in the emissions-reduced exhaust gas;
- the uncertainties for the activity data, the emission factor and emissions reductions.

The emissions-control technologies used include, in some cases, catalytic decomposition directly following ammonia combustion.

Until 2006, production quantities correlated with the N_2O emissions. Subsequently, a considerable decoupling of production quantities and N_2O emissions has become apparent that is due to use of emissions-reduction equipment.

NO_X **emission factor:**

For the NO_X emission factor, the default emission factor given in the *CORINAIR Guidebook*, 10 kg/t NH_3, is used (EMEP EEA Emission Inventory Guidebook, TFEIP-endorsed draft, May 2009).

4.3.2.3 Uncertainties and time-series consistency (2.B.2)

Activity data:

The activity-rate uncertainty, as provided by the operators, has been determined, as specified by the IVA / the Federal Environment Agency, in keeping with Equation 6.3 in IPCC GPGAUM. The pertinent uncertainty is ± 1 %.

Emission factor:

For the N_2O emission factor, the operators give an uncertainty of ± 5 %.

4.3.2.4 Category-specific quality assurance / control and verification (2.B.2)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

4.3.2.5 Category-specific recalculations (2.B.2)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.3.2.6 Planned improvements (category-specific) (2.B.2)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.3.3 Chemical industry: Adipic acid production (2.B.3)

4.3.3.1 Category description (2.B.3)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T	2.B.3 Chemical industry	Adipic acid production	N_2O	18,076.7	(1.48%)	338.3	(0.04%)	-98.1%

Gas	Method used	Source for the activity data	Emission factors used
N_2O	Tier 3	PS	PS
NO_X, CO	NA	NA	NE

The category *Chemical industry*: *adipic acid production* is a key category for N_2O emissions in terms of emissions level and trend.

On an industrial scale, adipic acid is produced via oxidation of a mixture of cyclohexanol and cyclohexanone with nitric acid. In that reaction, considerable amounts of nitrous oxide (N_2O) are formed.

Until the end of 1993, the two sole German producers emitted all of their nitrous oxide directly into the atmosphere. One producer has since put into operation a system for thermal decomposition of nitrous oxide into nitrogen and oxygen. Decomposition takes place nearly completely. In 2009, a second, additional (i.e. redundant) thermal N_2O-decomposition facility was added. N_2O-decomposition rates of over 99% are now being achieved.

At the end of 1997, the other producer put a catalytic reactor system into operation that, in constant operation, achieves an N_2O-decomposition rate of 97-98 %. At the end of 2009, a second, additional (i.e. redundant) decomposition reactor was added.

Since 2010, N_2O emissions have decreased further, significantly, as a result of the installation of the two redundant waste-gas treatment facilities.

In March 2002, operations were begun with a third producer's plant that also uses thermal N_2O decomposition. Following initial technical problems, the system has been in constant operation since 2003. This producer also has the option of using a redundant emissions-reduction system in cases when the first plant is down.

The overall fluctuations in the decomposition rates – and, thus, in the residual emissions – are the result of functional impairments in the emissions-control equipment, of planned interruptions in their operation and of variances in production volumes.

From 1990 to the present, production has nearly doubled, as a result of growth in demand.

4.3.3.2 Methodological issues (2.B.3)

Since 1990, the EF calculation for N_2O emissions from adipic acid production has been based on plant-specific data.

In those years in which no N_2O-reduction equipment was in place, the two producers provided data only on amounts produced. The nitrous oxide emissions for this period – until 1994, for one facility, and until 1997, for the second – were calculated with the IPCC default emission factor. These N_2O-emissions calculations are in keeping with the Tier 2 method. For the subsequent period, the producers, in addition to providing data on production and on N_2O emissions, also provided the background information, on a confidential basis, that is needed to assess the precision of the reported data.

Since then, all three producers have been measuring their nitrous oxide emissions continuously. The N_2O-emissions calculations are in keeping with the Tier 3 method in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

4.3.3.3 Uncertainties and time-series consistency (2.B.3)

IPCC GL 2006 specifies uncertainties of +/- 0.05% for plants with thermal decomposition and of +/- 2.5% for plants with catalytic decomposition. According to producers' information, the uncertainties, regardless of what reduction process is used, lie within a range of +/- 5 to 5.9 %. The range for uncertainties relative to production quantities is given as +/-0.06 to 1 %. The EF is thus assumed to have an uncertainty of 5.9 %.

4.3.3.4 Category-specific quality assurance / control and verification (2.B.3)

Due to a lack of relevant specialised staff, it was not possible to have quality control and quality assurance carried out, by category experts. This situation will be corrected as soon as the relevant person returns (normally, in connection with the next report). General and category-specific quality control, and quality assurance in conformance with the requirements of the QSE manual and its associated applicable documents, have been carried out by the Single National Entity. Data were collected, taken from previous years or determined on the basis of existing calculation routines.

Information provided by producers enjoys a high degree of confidentiality protection. For this reason, only emissions figures can be listed in the CRF tables. The reported emissions and activity data have been reviewed by a Federal Environment Agency expert and compared with industry figures and figures from other publications.

Two of the three producers have taken part in a JI project. The results of that project were compared with the inventory data, and the inventory data confirmed the project results.

4.3.3.5 Category-specific recalculations (2.B.3)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.3.3.6 Category-specific planned improvements (2.B.3)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.3.4 Chemical industry: Caprolactam, glyoxal and glyoxylic acid (2.B.4)

4.3.4.1 Category description (2.B.4)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/-	2B4 Chemical Industry	Caprolactam, glyoxal and glyoxylic acid production	N_2O	221.8	(0.02%)	0.0	(0.00%)	-100.0%

Gas	Angewandte Methode	Quelle der Aktivitätsdaten	genutzte Emissionsfaktoren
N_2O	NA	NS	NA

The category *Chemical industry*: *Caprolactam, glyoxal and glyoxylic acid* is not a key category for nitrous oxide (N_2O) emissions.

Industrially, ε-caprolactam is the most important lactam. It is used primarily for production of PA 6. There are two producers in Germany. The requirements for ε-caprolactam, which are also met via imports, increased until 2004. Since 2008, it has also been exported.

Glyoxal is used in the production of a wide range of products. It serves to improve product properties. There is one producer.

He reports that no glyoxal delivered to German customers is processed into glyoxylic acid in Germany. In addition, to our knowledge no glyoxylic acid is produced from other raw materials.

4.3.4.2 Methodological issues (2.B.4)

Activity data

The data on production of ε-caprolactam, for the years 1995 through 2008, were obtained from the Federal Statistical Office (STATISTISCHES BUNDESAMT, Fachserie 4, Reihe 3.1, Produzierendes Gewerbe, Produktion im Produzierenden Gewerbe ("manufacturing industry; production in the manufacturing industry"). Due to the small number of producers involved, the production-quantity figures in the official statistics have to be kept confidential. In 2009, the goods classification for production statistics on which the survey is based was brought into line with international NACE Rev.2 classification and the 2008 PRODCOM list. Since then, the produced quantities of ε-caprolactam have no longer been listed individually. For that reason, the production-quantity data are carried forward.

The production quantities for the years 1991 through 1994 were interpolated.

Ethandiol (ethylene glycol) is used as a raw material for the production of glyoxal. The sole German producer reports a production capacity of 60,000 t per year.

Emission factors

The best available technology for reducing nitrous oxide emissions from caprolactam production is thermal waste-gas treatment.

No process-related nitrous oxide emissions occur in connection with the glyoxal-production process used.

4.3.4.3 Uncertainties and time-series consistency (2.B.4)

The emission factors are based on producers' data. The uncertainties cannot be estimated, however. The new emission factors are valid for the entire time series. Fluctuations in the activity data have occurred over the period under consideration. The reasons for this are unknown. Since it was possible to obtain the production-quantity data largely from official statistics, the pertinent uncertainties may be considered small. In spite of the survey changes that have occurred within the period under consideration, the data are considered to be consistent.

4.3.4.4 Category-specific quality assurance / control and verification (2.B.4)

Due to a lack of relevant specialised staff, it was not possible to have quality control and quality assurance carried out, by category experts. This situation will be corrected as soon as the relevant person returns (normally, in connection with the next report). General and category-specific quality control, and quality assurance in conformance with the requirements of the QSE manual and its associated applicable documents, have been carried out by the Single National Entity. Data were collected, taken from previous years or determined on the basis of existing calculation routines.

4.3.4.5 Category-specific recalculations (2.B.4)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.3.4.6 Planned improvements (category-specific) (2.B.4)

Plans call for survey of other sources for data on ε-caprolactam-production quantities as of the year 2009, and for substantiation of the N_2O reductions achieved by other producers.Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.3.5 Chemical industry: Carbide production (2.B.5)

4.3.5.1 Category description (2.B.5)

KC	Category	Activity	EM of	1990 (kt)	(fraction)	2013 (kt)	(fraction)	Trend 1990-2013
-/-	2.B.5 Chemical Industry	Carbide production	CO_2	443.2	(0.04%)	10.9	(0.00%)	-97.5%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 3	PS	PS (CaC_2) NO (SiC)

The category *Chemical industry*: *Carbide production* is not a key category.

During the reunification period, calcium carbide production took place primarily in the new German Länder. A short time later, production there was discontinued, while only one producer remained in the old German Länder. According to the responsible specialised association within the VCI, no silicon carbide has been produced in Germany since 1993. Emissions from this sector thus no longer occur.

4.3.5.2 Methodological issues (2.B.5)

Activity data:

Since Germany has only one producer, the relevant data must be kept confidential. The producer communicates the data directly to the Federal Environment Agency on an annual basis. The data, as of the data for 1997, were obtained from the operator's life cycle assessment and from his annual environmental declarations pursuant to the EMAS (the facility has been certified since 1997). The only published data consists of those for amounts produced in the former GDR. Those data were published, until 1989, by that country's central statistical authority. Those figures were used, in combination with existing estimates for 1991 and 1992, to interpolate production in the new German Länder in 1990.

Emission factor:

The stoichiometric emission factor for CO_2 is 688 kg per tonne of calcium carbide (44 g mol^{-1} / 64 g mol^{-1}). Until 1992, this emission factor was used for production in the new German Länder.

Using covered furnaces, producers collect all of the carbon monoxide produced in the process and use it for energy generation. The resulting carbon dioxide serves as auxiliary material in production of calcium cyanamide and derived products. Reactions in these processes yield carbon dioxide in mineral form, as black chalk. In this form, it is used in agriculture. In 2012, carbide-furnace operations were smoothed out in a way that considerably reduced the amount of surplus furnace gas that had to be flared off. The new operational mode has also enabled the furnaces to run more "calmly", meaning that they produce fewer pressure surges that have to be buffered via raw-gas flares.

As a result, the emission factor for carbon dioxide from calcium carbide production is now substantially lower than it has been in previous years.

Upon request, the relevant producer provides the Federal Environment Agency with data on total emissions and on quantities produced. The emission factor is obtained as the product of activity data and emissions quantity.

4.3.5.3 Uncertainties and time-series consistency (2.B.5)

Consistency is not complete, due to the described need to estimate production amounts in the new German Länder.

The uncertainties relative to the data provided by the producer are considered slight overall.

4.3.5.4 Category-specific quality assurance / control and verification (2.B.5)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

Producers' relevant figures enjoy a high degree of confidentiality protection. For this reason, only emissions figures can be listed in the CRF tables. No calculations for verification could be carried out. It may be noted, however, that some of the figures have also been provided to licensing authorities and thus are considered trustworthy.

4.3.5.5 Category-specific recalculations (2.B.5)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.3.5.6 Planned improvements (category-specific) (2.B.5)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.3.6 Chemical industry: Titanium dioxide production (2.B.6)

One facility for production of titanium dioxide via the chloride process exists in Germany. In light of the facility's approved production capacity, and of the default factor for synthetic rutile, the pertinent CO_2 emissions are estimated to account for less than 0.05 % of total emissions. This estimate was made with confidential data that, by virtue of their confidentiality, cannot be presented here.

Since the greenhouse-gas emissions from the category titanium dioxide production account for less than 0.05 % of the total inventory (not including LULUCF), *and* since they would not exceed 500 kt CO_2 equivalents (significance thresholds pursuant to FCCC/SBSTA/2013/L.29/Add.1), and since annual recording cannot be assured (in keeping with FCCC/SBSTA/2013/L.29/Add.1, para 37), we opt not to report on this area (IPCC Guideline, 2006d). In addition, a compilation of all sources listed as "not estimated" is presented in Annex 5 in Chapter 21 of the present report.

4.3.7 Chemical industry: Soda-ash production (2.B.7)

4.3.7.1 Category description (2.B.7)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/-	2.B.7 Chemical Industry: soda ash	use of soda ash	CO_2	667.0	(0.05%)	471.3	(0.05%)	-29.3%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1	NS	CS

The category *Soda ash production* is not a key category.

In Germany, soda ash is produced only chemically. The country has 3 production facilities, all of which use[50] the Solvay process[51]. In principle, the CO_2 contained within the calcium carbonate used in the process is bound within the product, soda ash (Na_2CO_3), and is released – if at all – only when that product is used. But since production via the Solvay process yields a CO_2 surplus, process-related CO_2 emissions result.

In the calcination part of the process, coke is also used, and this produces additional (energy-related) carbon-dioxide emissions.

[50] Other processes that are less important in terms of the production quantities involved are not considered here, because they use carbon dioxide from sources other than limestone.

[51] Ammonia-soda process pursuant to Ernst Solvay

4.3.7.2 Methodological issues (2.B.7)

Activity data

The *Federal Statistical Office* determines the total amounts of soda ash produced in Germany. From 1995 to 2008, the sum total has comprised the categories of *light soda* (production number 2413 33 103, disodium carbonate in powder form, with a fill density of less than 700 g/l) and *heavy soda* (production number 2413 33 109, other disodium carbonate). Since 2009, light and heavy soda are reported in combination, in one position (notification number 2013 43 100). Of that quantity, only the portion "intended for sale" ("zum Absatz bestimmt") is taken into account. This prevents double-counting, since heavy soda is produced from light soda. Since Germany has only two producers, the production-quantity data, which are taken from official statistics, must be kept confidential.

Emission factor

The emission factor is calculated from the carbon dioxide emissions, as determined in keeping with the pertinent ETS-CO_2 balance, and from the production quantities involved. Since the production-quantity data, as taken from official statistics, has to be kept confidential, the relevant EF cannot be given here.

The coke quantity used in burning the relevant lime has already been included in the Energy Balance as a non-energy-related use (i.e. without inclusion of CO_2 emissions).

4.3.7.3 Uncertainties and time-series consistency (2.B.7)

Activity data

There are uncertainties regarding the production statistics given by the Federal Statistical Office, since – for example – the relation between light and heavy soda ash fluctuates widely, especially in the first years for which separate statistics are provided.

Emission factor

The uncertainty of the emission factor, with regard to production of soda ash, is calculated from the uncertainties for the ETS emission balance and the uncertainties for the pertinent production data.

4.3.7.4 Category-specific quality assurance / control and verification (2.B.7)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The CO_2 balance for determination of the relevant emissions is produced with the help of data from emissions trading. Those data have been fully checked and verified in the framework of the EU Emissions Trading System (ETS).

4.3.7.5 Category-specific recalculations (2.B.7)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.3.7.6 Category-specific planned improvements (2.B.7)

No further improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.3.8 Chemical industry: Petrochemical and carbon black production (2.B.8)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/T	**2.B.8 Petrochemical and carbon black production**		**CO_2**	**886.3**	**(0.07%)**	**1,980.2**	**(0.21%)**	**123.4%**
-/-	2B8 Petrochemical and carbon black production		CH_4	333.7	(0.03%)	464.0	(0.05%)	39.1%

Gas	Angewandte Methode	Quelle der Aktivitätsdaten	genutzte Emissionsfaktoren
CO_2	Tier 2 (Industrieruß) CS (Petrochemie)	NS	D (Industrieruß) CS (Petrochemie)
CH_4	Tier 1	NS	D
CO, SO_2	Tier 1 (Industrieruß)	NS	D (Industrieruß)
NMVOC	Tier 1 (Petrochemie)	NS	C & CS (Petrochemie)

The category *Chemical industry*: *Petrochemical and carbon black production* is a key source of CO_2 emissions in terms of trend. Carbon black production, which accounts for about 90% of the pertinent emissions, and which shows a sharply increasing emissions trend, dominates this category and is the main factor responsible for its classification as a key category.

4.3.8.1 Chemical industry: Petrochemicals (2.B.8 Petrochemicals)

4.3.8.1.1 Category description (2.B.8 Petrochemicals)

The petrochemicals sector produces basic organic chemicals, from natural gas and from petroleum fractions, that are processed into a great many different intermediate and end products (primarily polymers). Under 2.B.8, the 2006 IPCC Guidelines list production of (a) methanol, (b) ethylene, (c) ethylene chloride and vinyl chloride, (d) ethylene oxide and (e) acrylonitrile on account of the carbon dioxide and methane emissions such production can entail. Germany also has to consider these production areas in terms of their greenhouse-gas emissions.

From 1990 through 2005, production of the above-mentioned basic chemicals increased nationally. Since then, production volumes have been decreasing.

4.3.8.1.2 Methodological issues (2.B.8 Petrochemicals)

Activity data

The production-quantity data available with regard to production of the aforementioned products is only national; no installation-related data are available. The data, for the period as of 1990, are provided by the Federal Statistical Office in its Fachserie 4, Reihe 3.1, "Produzierendes Gewerbe, Produktion im Produzierenden Gewerbe" ("Manufacturing industries, production in manufacturing industries"). They include confidential data.

Since several different relevant production quantities are subject to confidentiality, all production quantities for the products in groups a) through e) are aggregated and then reported, together with the pertinent CO_2, CH_4 and NMVOC emissions, under 2.B.8g.

For determination of NMVOC emissions, production further products, in addition to production of methanol, ethylene, ethylene dichloride and vinyl chloride, ethylene oxide and acrylonitrile, is also taken into account.

CO_2 emission factors

Pursuant to Annex 1 Part 2 No. 27 German Greenhouse Gas Emission Allowance Trading Act (TEHG), all of the installations located in Germany for production of the aforementioned organic basic chemicals are subject to the EU Emissions Trading System (ETS), because their production outputs are greater than 100 t/d (36,500 t/a). This applied for the first time for the year 2013.

The total CO_2 emissions of the ETS installations (21 installations) in categories a) through e) amount to less than the relevant product-related CO_2 emissions as calculated with the standard emission factors of the now-applicable 2006 IPCC Guidelines. And this proves to be the case even though the total installation-related emissions from emissions trading include both emissions from combustion processes and other process-related emissions.

The comparative calculation indicates that the standard emission factors in the 2006 IPCC Guidelines do not correctly reflect the applicable national circumstances.

The Tier 3 method of the 2006 IPCC Guidelines calls for dividing the total CO_2 emissions into a) emissions from combustion processes (such as those taking place in boilers or cracking furnaces) and b) other process-related emissions. For the majority of ETS installations for production of organic basic chemicals, doing this would be extremely labour-intensive. Such a labour investment seems unjustified in light of the expected and estimated process-related emissions. The reason for this is that the installation-related CO_2 emissions of steam cracker units – which represent far and away the largest emitter group of relevance in this context – occur in combustion in cracking furnaces, auxiliary boilers or flares. In the German greenhouse-gas inventory, such combustion-related emissions are covered by reporting on the energy sector. For this reason, we have not quantified the relevant process-related emissions.

In the interest of the inventory's completeness, however, we have quantified the pertinent CO_2 emissions from flaring losses. In doing so, we consider only that fraction of flaring gases that can be assigned to the aforementioned processes.

Since ETS data is not available for all products for the period prior to 2013, the CO_2 emissions are calculated on the basis of a CO_2 emission factor derived for 2013 and of the annually produced quantities of the relevant products. Because residual gases and flare gases are often transported from installation to installation, it seems useful to use an emission factor that is aggregated over all of the products considered in this category. Such aggregation addresses the reasons, as given in Vol. 3 Chapter 1 of the 2006 IPCC Guidelines, for uncertainties in allocation of emissions from the aforementioned production processes, to the products listed in categories a) through e), and the CO_2 emissions from flares of the aforementioned installations are not necessarily tied to one of the products in categories a) through e). At chemical industry sites, gases from various different production processes that need to be flared are often flared in a central flare that, in terms of its legal approval, is allocated only to one production installation. As a result, in such cases, the emissions quantity allocated to a given product can be greater than the emissions quantity actually caused by the relevant production process. On the other hand, gases from processes a) through f) that need to be flared may be transported to a flare in an installation that is not considered in the present context, with the result that the pertinent emissions quantity is lower than the actual product-related emission quantity.

The flare emissions allocated to the various relevant installations for the year 2013 are summed and then divided by the total production quantity for all products produced, in that year; this yields the emission factor for flaring losses ($EF_{flaring}$). It amounts to 14.8 kg/t product. That emission factor has been used to retroactively calculate annual emissions, using a Tier 1 method, back to 1990.

CH_4 emission factors

The IPCC Guidelines list all aforementioned installations as potential emission sources.

Pursuant to Point 5.2.5 of the TA Luft (Technical Instructions on Air Quality Control), German plants subject to the TA Luft must meet a standard of 50 mg/m³ (total carbon) for total mass concentration of organic substances (NMVOC and CH_4, but not including organic substances in dust form). The current state of the art provides for thermal post-combustion of volatile organic substances from plants for production of primary organic chemicals.

For ethylene, methanol, dichloroethane and styrene, a major German producer reports that no further point-source methane emissions occur in those areas, thanks to thermal post-combustion.

No data from emissions trading can be used for reporting on methane emissions from chemical industry installations, since the currently valid German Greenhouse Gas Emission Allowance Trading Act (TEHG) does not mandate reporting on CH_4. Furthermore, since no information from other installation operators is available that could be used for quantification of CH_4 emissions, the methane emissions for all petrochemical industry installations as a whole are calculated via a Tier 1 method, with the IPCC 2006 standard emission factors, where those factor also take account of diffuse emissions.

NMVOC emission factors

The NMVOC emission factors for polystyrene were taken from the European Commission (EC, 2006a, BAT Reference Document (BREF), Production of Polymers), while for other products figures of German producers were used (these figures are available as confidential data). Until 1994, the default factors in EMEP/CORINAIR Emission Inventory Guidebook were used. Relevant detailed reporting is provided in the Informative Inventory Report pursuant to the CLRTAP.

4.3.8.1.3 Uncertainties and time-series consistency (2.B.8 Petrochemical industry)

CO_2

The "backward projection" of data from the 2013 emissions reports, to earlier years (back through 1990) is subject to large uncertainties. On the one hand, in many cases the flare emissions reported in the ETS for report year 2013 were determined and reported on the basis of estimates. On the other, it must be assumed that CO_2 emissions from the flares allocated to the relevant installations, under licensing law, cannot really be completely assigned to production of the products under consideration in this context. For example, gases (including waste gases) from other production processes are burned in the flares under consideration here. What is more, over time, installations can make local internal changes in routing of waste gases from various processes. Such changes further increase the uncertainty of "back-calculated" product-specific emissions. Furthermore, the production capacities of the relevant steam cracker units have not remained constant over the years under consideration.

In derivation of the emission factor, it was not possible to take account of all significant emission sources. As a result, the emissions are underestimated. For this reason, a high uncertainty, of +200/-1, is assumed.

Consistency of the time series is assured, because a consistent method was used to calculate the emissions back through 1990, and because there are no gaps in the activity data and no jumps (discontinuities) in the emission factor.

CH_4

In the 1980s, thermal post-combustion was introduced on a large scale. As a result, point-source emissions of organic substances from German plants are likely to be low. Use of standard emission factors is probably leading to overestimation of the emissions. Since the resulting uncertainties cannot be estimated, the Tier-1-method uncertainties given in Table 3.27 of the 2006 IPCC Guidelines are being assumed.

Consistency of the time series is assured, because a consistent method was used to calculate the emissions back through 1990, and because there are no gaps in the activity data and no jumps (discontinuities) in the emission factors.

Activity data

The activity data have been taken from official statistics for which inaccuracies of ±20 in statistical data collection are assumed.

4.3.8.1.4 Category-specific quality assurance / control and verification (2.B.8 Petrochemical industry)

Due to a lack of relevant specialised staff, it was not possible to have quality control and quality assurance carried out, by category experts. This situation will be corrected as soon as the relevant person returns (normally, in connection with the next report). General and category-specific quality control, and quality assurance in conformance with the requirements of the QSE manual and its associated applicable documents, have been carried out by the Single National Entity. Data were collected, taken from previous years or determined on the basis of existing calculation routines.

The quantity of ethylene produced in 2013, as reported by the Federal Statistical Office, was compared with the relevant APPE capacity data. The resulting national standard capacity-utilisation factor of 0.858 is comparable to the standard capacity-utilisation factor pursuant to Article 18 (2) of Commission Decision 2011/278/EU.

4.3.8.1.5 Category-specific recalculations (2.B.8 Petrochemical industry)

No recalculations are required.

4.3.8.1.6 Category-specific planned improvements (2.B.8 Petrochemical industry)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.3.8.2 Chemical industry: Carbon black production (2.B.8 Carbon black)

4.3.8.2.1 Category description (2.B.8 Carbon black)

Carbon black is produced via incomplete combustion of gaseous or liquid hydrocarbons. The relevant production processes can be controlled and monitored so as to conform to defined specifications for carbon black. In Germany, carbon black is produced from hard-coal-tar oils (anthracene oils) and from oils produced by petroleum refineries (pyrolysis / cracking oils).

A total of 90 % of the carbon black produced in Germany is produced via the furnace black process. The remaining 10 % is produced via the flame-pressure and gas black processes.

4.3.8.2.2 Methodological issues (2.B.8 Carbon black)

CO_2 emissions

For CO_2 from carbon-black production, the default emission factor from the IPCC Guidelines 2006 is used (Table 3.23, Furnace black process (default process), primary feedstock).

CH_4 emission factors

The international guidelines give very little attention to this category. The IPCC Guidelines list carbon black production as a potential emission source.

Pursuant to Point 5.2.5 of the TA Luft (Technical Instructions on Air Quality Control), German plants subject to the TA Luft must meet a standard of 50 mg/m³ (total carbon) for total mass concentration of organic substances (NMVOC and CH_4, but not including organic substances in dust form). In keeping with these technical standards, the three German producers of carbon black report an emission factor of 0.027 kg methane per tonne of carbon black. Since the relevant technology has been in service since the 1970s, this EF is rounded off to 0.03 kg/t and applied to the entire time series.

Emission factors for NMVOC, CO and SO_2

For pollutants other than the methane considered above, the emission factors listed in the following table were used for Germany.

Table 144: Emission factors used in Germany for other pollutants

	Carbon black [kg CO / t]	Carbon black [kg SO_2/t][52]
1990	4.8/5	19.5/ [(53)]
1991	4.6/5	19/20
1992	4.4/5	18.5/20
1993	4.2	18
1994	4	17.5
1995	3.75	17
1996	3.5	16
1997	3.25	15
1998	3	14
1999	2.9	13.4
2000	2.8	12.8
2001	2.7	12.54
2002	2.65	12.28
2003	2.6	12.0
2004	2.55	11.7
2005	2.5	11.5
2006	2.5	11.2
2007	2.5	10.9
2008	2.5	10.6
2009	2.5	10.3
since 2010	2.5	10.0

The EF figures for CO and SO_2, for production of carbon black, are based on the BREF Large Volume Inorganic Chemicals - LVIC – S (EC, 2007) and are identical with the default values presented in the 2008 CORINAIR manual (first order draft).

Activity data

The production statistics of the Federal Statistical Office include the following products (cf. the following table).

Table 145: Reporting numbers (Meldenummern) from production statistics

Line	Carbon black
through 1994	4113 70
since 1995	2413 11 300
since 2009	2013 21 300

The figure for carbon-black production in the new German Länder in 1990 was taken from the Statistical Yearbook (Statistisches Jahrbuch) for the Federal Republic of Germany (*FEDERAL STATISTICAL OFFICE*, 1992: p. 234); the figures for 1991 and 1992 were estimated, due to confidentiality requirements. The other data for carbon-black production as of 1990 were obtained from the Federal Statistical Office (*STATISTISCHES BUNDESAMT*, Fachserie 4, Reihe 3.1, Produzierendes Gewerbe, Produktion im Produzierenden Gewerbe ("manufacturing industry; production in the manufacturing industry").

4.3.8.2.3 Uncertainties and time-series consistency (2.B.8 Carbon black)

The time series shows fluctuations in the activity data. These remain to be analysed.

[52] Where two EF are listed, the second figure refers to the new German Länder.
[53] No EF is listed for the new German Länder, since these SO_2 emissions can be taken account of only as a lump sum.

4.3.8.2.4 Category-specific quality assurance / control and verification (2.B.8 Carbon black)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

4.3.8.2.5 Category-specific recalculations (2.B.8 Carbon black)

No recalculations are required.

4.3.8.2.6 Category-specific planned improvements (2.B.8 Carbon black)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.3.9 Chemical industry: Flurochemical production (2.B.9)

KC	Category	Activity	EM of	1995 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1995-2013
L/T	**2.B.9 Fluorochemical production**		**HFC**	**5,335.2**	**(0.44%)**	**46.7**	**(0.00%)**	**-99.1%**
-/-	2.B.9 Fluorochemical production		SF6	159.6	(0.01%)	101.0	(0.01%)	-36.7%

Gas	Method used	Source for the activity data	Emission factors used
HFC	Tier 3	PS	PS
SF_6	Tier 3	PS	PS

The category *Fluorochemical production* is a key category for HFC emissions in terms of emissions level and trend. It is subdivided into 2.B.9.a By-product emissions and 2.B.9.b Fugitive emissions.

4.3.9.1 By-product emissions (2.B.9.a)

4.3.9.1.1 Category description (2.B.9.a)

For process-related reasons, production of HCFC-22 produces up to 3 % HFC-23 as a by-product. For technical reasons, even when the HFC-23 is subjected to further processing (for example, to produce refrigerants) or is collected and then broken down into other substances, some HFC-23 is always released into the atmosphere.

Germany formerly had two production plants for HCFC-22. Those two plants, which were operated by a single company, were located in Frankfurt and Bad Wimpfen. In 1995, a CFC-cracking plant went into operation in Frankfurt that cracked, at high temperature, excess HFC-23 produced during production of HCFC-22 and that recovered hydrofluoric acid; i.e. no significant emissions were produced. HFC-23 produced at the second German production facility was captured in large amounts at the production system itself; the substance was then sold as a refrigerant or – following further distillative purification – as an etching gas for the semiconductor industry. Beginning in 1999, the excess amount that could not be sold was delivered to the cracking facility in Frankfurt. That measure substantially reduced emissions. In mid-2010, HCFC-22 production was terminated at one site. At the other site, it was significantly reduced, and all remaining production serves teflon production. Since the installation is directly connected to a CFC-cracking plant, only very slight emissions occur.

4.3.9.1.2 Methodological issues (2.B.9.a)

In keeping with manufacturer information from 1996, HFC-23 emissions are assumed to have remained constant in the years 1990 to 1994.

Beginning in 1995, the producer calculated emissions, via a mass-balance procedure, on the basis of HCFC-22 production, HFC-23 concentrations in exhaust gas (as measured annually), sales of HFC-23 and quantities of HFC-23 delivered to the cracking plant. For reporting year 1995, emissions-reduction measures (the cracking plant) for the first production plant were assumed to have been in place since mid-year. Since report year 2011, the relevant production quantities have been estimated by experts, and the resulting estimates have been used to determine the emissions. The estimates are made in light of comparable production facilities in other European countries.

Emission factors

An emission factor of 0.05 is assumed for the period as of 2011.

Emissions

Until 2011, the relevant HFC-23 emissions were reported by the producer. Thereafter, experts' assessments were used.

Since there are fewer than three producers in Germany, the emissions data are confidential. The HFC are reported as an "unspecified mix" in 2.B.9, as an aggregate of 2.B.9a and 2.B.9b.

4.3.9.1.3 Uncertainties and time-series consistency (2.B.9.a)

The production figures used as a basis for emissions calculation may be considered highly accurate until 2011, since they come directly from the producer's internal records. Thereafter, the uncertainty increases somewhat, although it can be minimized retroactively via comparison with E-PRTR data.

4.3.9.1.4 Category-specific quality assurance / control and verification (2.B.9.a)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

4.3.9.1.5 Category-specific recalculations (2.B.9.a)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.3.9.1.6 Category-specific planned improvements (2.B.9.a)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.3.9.2 Production-related emissions (2.B.9.b)

4.3.9.2.1 Category description (2.B.9.b)

In Germany, one company produces these gases; its HFC und SF_6 production takes place at two locations. Emissions trends are tied to trends in amounts produced. While SF_6 and HFC-134a are produced in Germany, until 2008 no complete synthesis of HFC-227ea was carried out in Germany. Part of the HFC-227ea produced in Tarragona, Spain, undergoes subsequent distillation, in Germany, to pharmaceutical purity (use in dosing aerosols). That process produces emissions as a result of minor gas losses.

HFC-134a has been produced since 1994, while HFC-227ea has been produced since 1996.

4.3.9.2.2 Methodological issues (2.B.9.b)

Emission factors

It is possible to calculate an emission factor from the emissions and production quantities reported by the producer until 2010. The resulting factor is not published, however, because the underlying data are confidential. That factor has also been assumed to apply for the subsequent years.

Activity data

Because the HFC producer in Germany is the country's sole producer, that company's data are confidential. Until 2010, the emissions and production quantities were reported to the Federal Environment Agency, but only in aggregated form. Since 2011, data of the Federal Statistical Office have been used.

4.3.9.2.3 Uncertainties and time-series consistency (2.B.9.b)

The production figures used as a basis for emissions calculation may be considered highly accurate, since they come directly from the producer's internal records or from official statistical surveys.

4.3.9.2.4 Category-specific quality assurance / control and verification (2.B.9.b)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

4.3.9.2.5 Category-specific recalculations (2.B.9.b)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.3.9.2.6 Category-specific planned improvements (2.B.9.b)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.3.10 Chemical industry – other: Emissions from other production processes (2.B.10)

4.3.10.1 Category description (2.B.10)

The precursor substances from production of fertilisers and sulphuric acid are reported in this category. While N_2O emissions from production of dodecanedioic acid are described here, they are included in 2.G.3, for reasons of confidentiality.Among dicarboxylic acids, dodecanedioic acid ranks second, in terms in terms of the quantities involved. It is surpassed only by adipic acid in this regard. There is one producer in Germany. That producer's installation has a capacity of 18,000 t per year[54].

4.3.10.2 Methodological issues (2.B.10)

N_2O emissions

The N_2O emissions were calculated via a Tier 1 method. The relevant production-quantity data were taken from a one-time query of the producer. The data are carried forward. The N_2O emissions have been reduced by 95%, via waste-gas treatment in a treatment facility.

4.3.10.3 Uncertainties and time-series consistency (2.B.10)

Time-series consistency is assured, because the data set resulting from one-time data collection has also been applied to the other years involved. Since the figures are based on qualitative information provided by the manufacturer, and refer only to one year, large uncertainties, of + 300 % / - 20 %, have to be assumed.

4.3.10.4 Category-specific quality assurance / control and verification (2.B.10)

Due to a lack of relevant specialised staff, it was not possible to have quality control and quality assurance carried out, by category experts. This situation will be corrected as soon as the relevant person returns (normally, in connection with the next report). General quality control, and quality assurance in conformance with the requirements of the QSE manual and its associated applicable documents, have been carried out by the Single National Entity. Data were taken from previous years or determined on the basis of existing calculation routines.

4.3.10.5 Category-specific recalculations (2.B.10)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.3.10.6 Category-specific planned improvements (2.B.10)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

[54] Source: Industrielle Organische Chemie, Hans-Jürgen Arpe, Wiley-VCH, 2007

4.4 Metal production (2.C)

Category 2.C is divided into the sub-categories 2.C.1 through 2.C.5. In the CSE emissions database, sub-category Iron and steel production (2.C.1) includes sinter production, pig-iron production, iron and steel production and tempered castings. Production of ferroalloys (2.C.2) has only minor importance in Germany. For this reason, it is not further subdivided in the present report. Aluminium production (2.C.3) is sub-divided into primary aluminium and resmelted aluminium. Use of SF_6 in aluminium and magnesium production (2.C.4) is not further sub-divided. In the Central System of Emissions (CSE), sub-point (2.C.5) comprises lead production. (2.C.6) comprises zinc production. (2.C.7) includes copper production (2.C.7a), nickel production (2.C.7b) and other production (2.C.7c). No greenhouse-gas emissions result in Germany from these categories.

4.4.1 Metal production: Iron and steel production (2.C.1)

4.4.1.1 Category description (2.C.1)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T/2	**2.C.1 Metal production: Iron and steel production**	**Steel (integrated production)**	**CO_2**	**22,810.3**	**(1.87%)**	**13,978.0**	**(1.50%)**	**-38.7%**
-/-	2.C.1 Metal production: Iron and steel production	Steel (integrated production)	N_2O	26.5	(0.00%)	12.8	(0.00%)	-51.9%
-/-	2.C.1 Metal production: Iron and steel production	Steel (integrated production)	CH_4	4.7	(0.00%)	5.3	(0.00%)	12.9%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	NS	CS
CH_4	Tier 2	NS	CS
N_2O	CS	NS	CS
NO_X, CO, NMVOC, SO_2	Tier 2	NS	CS

The category *Iron and steel production* is a key source of CO_2 emissions in terms of emissions level and trend and of Tier 2 analysis.

In 2013, a total of 29.2 million t of raw steel, from ore, was produced in Germany in six integrated steel works. Electric steel production amounted to 13.5 million t.

4.4.1.2 Methodological issues (2.C.1)

This sector comprises process-related emissions from primary steel production (via sinter plants, blast furnaces and oxygen-steel plants) and from electric steel plants.

Other structural elements in this category (foundries: iron and steel casting (including malleable casting); steel production: rolled-steel production) are used for calculation of other pollutant emissions (not greenhouse-gas emissions).

Process-related CO_2 emissions from primary steel production in integrated smelters result primarily from use of reducing agents in blast furnaces. CO_2 emissions from limestone inputs in sinter plants and in pig-iron production (including the CO_2 emissions from the lime kilns operated by the steel industry), and CO_2 emissions from electrode consumption in electric steel production, are added to process-related emissions in sector 2.C.1.

Very little direct-reduced iron (DRI; sponge iron) is produced in Germany (only about 0.5 million t. per year). Annual production-quantity data, which are available only as of the year 2010, are confidential, because they refer solely to a single installation. No activity data are available for earlier years, because sponge-iron production was not listed separately as such in official statistics (Statistisches Bundesamt, Fachserie 4, Reihe 8.1) and because relevant production data cannot be determined from available data.

The CO_2 emissions that occur in sponge-iron production result from the use of natural gas, i.e. from use, as reducing agents, of H_2 and CO obtained from natural gas. The relevent quantities of natural gas used are included, throughout the entire time series, in the natural-gas inputs in the steel industry that are reported under 1.A.2.a. Consequently, the CO_2 emissions resulting from sponge-iron production are also included, throughout the entire time series, in the emissions reported under 1.A.2.a.

The process-related CO_2 emissions from sponge-iron production cannot be listed separately under 2.C.1, because such disclosures could be used to derive the confidential production-quantity data for the relevant installation.

Method for calculating the CO_2 emissions resulting from use of reducing agents in blast furnaces

Pursuant to the IPCC Guidelines, the CO_2 emissions in category 2.C.1 are to be determined via a carbon balance. The reason for this requirement is that virtually all of the carbon used for primary steel production is subsequently released into the atmosphere, as CO^2, in later energy-related use, or in flaring, of the blast furnace gas that forms in the blast furnace or of the basic oxygen furnace gas that forms in the oxygen steel converter. The share of carbon that remains in produced steel, or in that portion of pig iron that is not processed into steel, is not important by comparison to the CO_2 emissions related to use of reducing agents[55].

The inputs of reducing agents in blast furnaces, and material inputs in converters, are statistically recorded in great detail. The Steel Institute VDEh provides the relevant data to the Federal Environment Agency annually. The carbon content in the various materials used is calculated from emissions trading data. CO_2 emission factors for use of blast furnace gas and basic oxygen furnace gas are also available from emissions trading. The input gas quantities are taken from energy statistics. Calculation on the basis of a) carbon inputs and of b) carbon removals via use of blast-furnace / basic oxygen furnace gas yields a difference. Those CO_2 emissions are reported in category 2.C.1. Only part of all energy-related use of blast furnace gas and basic oxygen furnace gas takes place in category 2.C.1 (this is the energy-related use in hot-blast stoves in blast furnaces). Such gas is also used for other process combustion in the iron and steel industry (1.A.2.a); in coking plants, for bottom heating of coking furnaces (1.A.1.c); and for electricity generation in public power stations (1.A.1.a) and industrial power stations (1.A.2.f). Energy statistics provide data on top-gas and converter-gas consumption in all of the aforementioned categories. Consequently, the CO_2 emissions resulting from reducing-agent inputs for primary steel production are divided among all categories in which blast furnace gas and basic oxygen furnace gas are burned and, thus, CO_2 is actually emitted (cf. the following figure).

[55] The average carbon fraction in the more than 2000 types of steel produced in Germany is normally considerably smaller than 2%. It is not recorded statistically, however. In any case, the pertinent deduction of non-energy-related carbon is extremely small (<1.5 %) in comparison to the total CO_2 emissions from primary steel production. Since only about 3% of the pig iron produced in Germany is not processed into oxygen steel, the pertinent deduction of non-energy-related carbon is also marginal (ca. 0.1%).

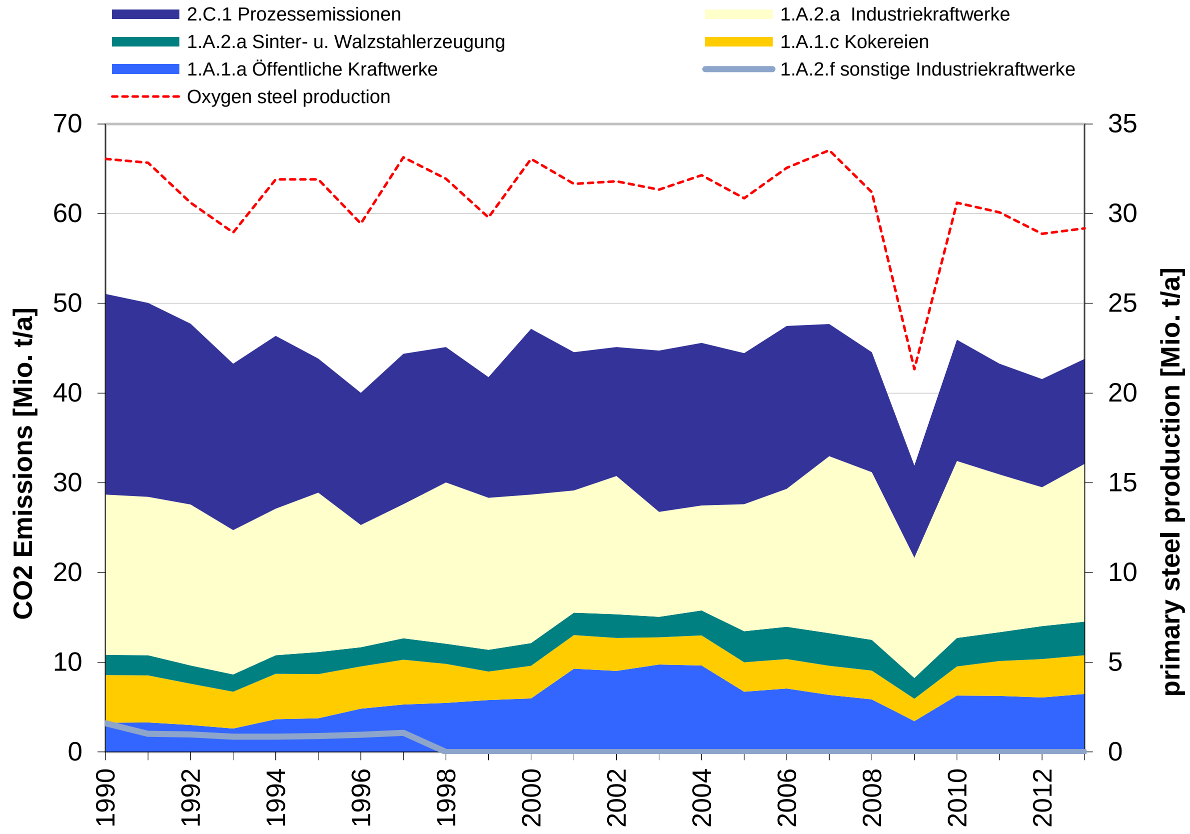

Figure 46: Chronological trend and category allocation of the CO_2 emissions resulting from use of reducing agents for primary steel production and from use of blast furnace gas [2.C.1 Process emissions; 1.A.2 a Sinter and rolled steel production; 1.A.1.a Public power stations; Oxygen steel production; 1.A.2.a Industrial power stations; 1.A.1.c Coking plants; 1.A.2.f Other industrial power stations]

The sum of the CO_2 emissions shown shows good correlation with the activity data reported for primary steel production (cf. the broken red line). Annual fluctuations in the individual categories are probably due to changes in allocation of individual plants within official statistics. Such fluctuations have practically no impact on the total sum of reported emissions, however.

Table 146: CO_2 emissions from primary steel production (including top-gas use)

Mt CO_2	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1.A.1.a Public power stations	3.244	3.291	3.015	2.631	3.647	3.764	4.816	5.305	5.465	5.808
1.A.1.c Coking plants	5.340	5.251	4.590	4.083	5.066	4.924	4.707	4.969	4.362	3.145
1.A.2.a Sinter and rolled-steel production	2.228	2.256	2.046	1.936	2.081	2.445	2.151	2.419	2.255	2.444
1.A.2.a Industry power stations	17.886	17.660	17.927	16.098	16.326	17.759	13.624	14.935	17.975	16.933
1.A.2.f Other industry power stations	3.206	2.025	1.942	1.707	1.720	1.770	1.932	2.144	0.000	0.000
2.C.1 Process emissions	22.354	21.591	20.164	18.514	19.252	14.938	14.731	16.764	15.087	13.442
Mt CO_2	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
1.A.1.a Public power stations	5.956	9.284	9.030	9.766	9.640	6.738	7.086	6.370	5.851	3.425
1.A.1.c Coking plants	3.652	3.741	3.684	3.029	3.356	3.247	3.281	3.226	3.226	2.500
1.A.2.a Sinter and rolled-steel production	2.520	2.487	2.629	2.265	2.788	3.461	3.603	3.642	3.437	2.315
1.A.2.a Industry power stations	16.573	13.627	15.406	11.709	11.695	14.164	15.351	19.748	18.675	13.429
1.A.2.f Other industry power stations	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.C.1 Process emissions	18.453	15.435	14.399	17.963	18.131	16.850	18.150	14.716	13.378	10.278
Mt CO_2	**2010**	**2011**	**2012**	**2013**						
1.A.1.a Public power stations	6.276	6.258	6.080	6.462						
1.A.1.c Coking plants	3.245	3.895	4.289	4.341						
1.A.2.a Sinter and rolled-steel production	3.198	3.217	3.646	3.715						
1.A.2.a Industry power stations	19.705	17.553	15.512	17.590						
1.A.2.f Other industry power stations	0.000	0.000	0.000	0.000						
2.C.1 Process emissions	13.527	12.367	12.046	11.719						

In the iron and steel industry, secondary fuels are used only in pig iron production in blast furnaces. To date, these materials have not yet been included in national statistics and the Energy Balance. For this reason, the data used consisted of figures provided by the Wirtschaftsvereinigung Stahl steel-industry association. Since the secondary fuels are used solely as substitute reducing agents, in place of coke, the CO_2 emissions resulting from their use are also included in the CO_2 emissions determined via inputs of blast furnace gas and basic oxygen furnace gas and do not have to be calculated separately.

Determination of CO_2 emissions from limestone inputs in pig iron production

CO_2 emissions from limestone use are determined in accordance with Tier 1 (UBA 2006, FKZ 20541217/02). The steel industry uses limestone ($CaCO_3$) only in aggregation of iron ores in sinter plants and in pig iron production in blast furnaces. In oxygen steel and electric steel mills, burnt lime for steel-mill applications (CaO) is used as a slag former (as a rule, it is purchased from the lime industry sector); the CO_2 emissions released in producing that burnt lime are thus already reported under 2.A.2. Only one steel mill meets its lime requirements with the help of lime kilns of its own whose production quantities, and related CO_2 emissions, are not included in the data reported under 2.A.2. The production quantities of those lime kilns are estimated on the basis of the following assumptions:

1. The lime kilns produce exactly as much burnt lime as is required by the associated steel mill. This means that no considerable additional quantities of burnt lime are purchased, provided to other companies or stored for later use.
2. The steel mill's specific lime consumption is estimated, on the basis of data obtained from emissions trading, as 65 kg lime / t crude steel. That figure is in keeping with the

ratio of the lime kilns' production capacity to the steel mill's capacity when the facilities were commissioned (1983/84). What is more, that figure lies within the range given by the BREF (Best Available Techniques Reference Document) for iron and steel production and by the website of the BV Kalk German lime-industry association (cf. http://www.kalk.de/rohstoff-kalk/einsatzgebiete/eisen-und-stahl).

3. For the years as of 2005, data on the mill's crude-steel production were taken from the mill's website[56]. For those years for which the mill's crude-steel-production data have not been made publicly available, it is assumed that the data are in keeping with overall economic trends for oxygen-steel production in Germany (in a constant ratio of 1:14.8).

From the so-determined activity data (quantity of burnt lime produced), only the raw-material-related CO_2 emissions, calculated via a stoichiometric EF, are reported in 2.C.1 – in a procedure similar to that used for 2.A.2 (cf. Table 147)). The CO_2 emissions from the fuels used for operation of the lime kilns, emissions which are not separately listed in the Energy Balance, are included in the emissions reported under 1.A.2.

Until 2004, limestone inputs in sinter and pig iron production were published as part of iron and steel statistics (*FEDERAL STATISTICAL OFFICE* Fachserie 4, Reihe 8.1). Since then, they have to be calculated from the production quantities of sinter and pig iron reported by the association, via specific input factors (i.e. kg of limestone per tonne of sinter or pig iron) (reported in the framework of the so-called "BGS form" (Fuel, gas and electricity industries of blast furnaces, steelworks and rolling mills; and forging plants, press works and hammer mills, including the various other plants (without their own coking plants)). Multiplying the activity data for limestone inputs by the stoichiometric emission factor for limestone produces the CO_2-emissions figures given in Table 147.

Table 147: Limestone inputs in the steel industry; and the steel industry's own production of burnt lime, and the resulting CO_2 emissions

Year	Limestone input [t/a]		Own production	CO_2 emissions [t/a]		
	Blast furnaces	Sinter plant	Burnt lime [t/a]	Limestone inputs	Lime production	Total
1990	755,737	4,680,775	153,918	2,392,065	114,823	2,506,888
1991	757,000	4,532,000	147,439	2,327,160	109,990	2,437,150
1992	666,000	4,198,000	136,560	2,140,160	101,874	2,242,034
1993	627,000	3,891,000	129,458	1,987,920	96,575	2,084,495
1994	733,000	4,173,153	140,003	2,158,707	104,443	2,263,150
1995	751,000	4,600,000	139,973	2,354,440	104,420	2,458,860
1996	686,000	4,350,000	129,177	2,215,840	96,366	2,312,206
1997	629,000	4,471,000	145,351	2,244,000	108,432	2,352,432
1998	677,000	4,588,000	140,157	2,316,600	104,557	2,421,157
1999	817,000	4,144,000	130,704	2,182,840	97,505	2,280,345
2000	924,000	4,273,000	144,991	2,286,680	108,163	2,394,843
2001	866,000	4,136,000	138,859	2,200,880	103,588	2,304,468
2002	831,000	3,940,000	139,538	2,099,240	104,096	2,203,336
2003	832,525	4,046,711	137,468	2,146,864	102,551	2,249,415
2004	847,689	4,209,871	140,977	2,225,326	105,169	2,330,495
2005	787,724	4,306,067	134,550	2,241,268	100,374	2,341,642
2006	822,920	4,410,408	162,500	2,302,664	121,225	2,423,889
2007	840,868	4,608,067	149,500	2,397,531	111,527	2,509,058
2008	790,216	4,541,174	136,500	2,345,812	101,829	2,447,641
2009	547,680	3,496,405	97,500	1,779,397	72,735	1,852,132

[56] http://www.arcelormittal-ehst.com/unternehmen/zahlen+%26+fakten?lang=de

Year	Limestone input [t/a]		Own production	CO_2 emissions [t/a]		
	Blast furnaces	Sinter plant	Burnt lime [t/a]	Limestone inputs	Lime production	Total
2010	799,679	4,045,042	130,000	2,131,677	96,980	2,228,657
2011	782,420	3,457,145	123,500	1,865,408	92,131	1,957,539
2012	757,355	3,912,824	117,000	2,054,879	87,282	2,142,161
2013	760,932	3,926,706	130,000	2,062,561	96,980	2,159,541

Source: until 2004: Limestone inputs were calculated by the "limestone balance" project ("Kalksteinbilanz"; UBA 2006, FKZ 20541217/02);
as of 2005: calculations via the product-specific factors determined in the aforementioned project

Determination of CO_2 emissions from electrode consumption in electric steel production

In electric steel production, CO_2 emissions occur directly via consumption of graphite electrodes. These emissions must also be allocated to process-related CO_2 emissions for steel production. They are calculated from the quantity of produced electric steel, via an emission factor (7.4 kg/t) that was updated in 2009, in a research project (UBA/BFI 2012), and that is based on the specific electrode consumption per tonne of electric steel (2.06 kg/t), its carbon content (98%) and the relevant stoichiometric factor (3.667 t CO_2/t C). The contribution from electrode combustion in electric steel production, at about 0.2% of total CO_2 emissions in iron and steel production, is insignificant.

Determination of the total CO_2 emissions from iron and steel production to be reported under 2.C.1

The total process-related emissions to be reported under 2.C.1 consist of the following:

12. the CO_2 emissions resulting from use of reducing agents in primary steel production, where the relevant blast furnace gas and basic oxygen furnace gas is not used in other categories and thus reported under other categories as CO_2 emissions,
13. the CO_2 emissions from limestone inputs in pig iron production and from the steel industry's own production of burnt lime, and
14. the CO_2 emissions from electrode consumption in electrical steel production.

The relevant so-determined emissions quantities are shown in Table 149.

Table 148: Total process-related emissions to be reported under 2.C.1

Year	CO_2 emissions from use of reducing agents, where not reported in other categories [t/a]	CO_2 emissions from limestone inputs and from the steel industry's own production of burnt lime [t/a]	CO_2 emissions from electrode consumption [t/a]	2.C.1 total [t/a]
1990	22,353,946	2,506,888	75,242	**24,936,076**
1991	21,591,077	2,437,150	68,464	**24,096,690**
1992	20,164,038	2,242,034	64,358	**22,470,429**
1993	18,513,568	2,084,495	59,840	**20,657,903**
1994	19,252,351	2,263,150	65,783	**21,581,284**
1995	14,937,965	2,458,860	74,794	**17,471,619**
1996	14,730,602	2,312,206	76,291	**17,119,099**
1997	16,764,166	2,352,432	87,552	**19,204,149**
1998	15,087,142	2,421,157	89,196	**17,597,495**
1999	13,442,149	2,280,345	90,457	**15,812,951**
2000	18,452,679	2,394,843	98,251	**20,945,774**
2001	15,435,485	2,304,468	96,961	**17,836,915**
2002	14,398,814	2,203,336	97,381	**16,699,530**
2003	17,963,060	2,249,415	99,048	**20,311,523**
2004	18,131,485	2,330,495	104,984	**20,566,964**

Year	CO_2 emissions from use of reducing agents, where not reported in other categories [t/a]	CO_2 emissions from limestone inputs and from the steel industry's own production of burnt lime [t/a]	CO_2 emissions from electrode consumption [t/a]	2.C.1 total [t/a]
2005	16,850,243	2,341,642	100,780	**19,292,666**
2006	18,149,600	2,423,889	108,206	**20,681,695**
2007	14,716,286	2,509,058	110,721	**17,336,065**
2008	13,377,604	2,447,641	107,945	**15,933,190**
2009	10,277,669	1,852,132	83,587	**12,213,388**
2010	13,526,753	2,228,657	97,446	**15,852,856**
2011	12,367,111	1,957,539	104,741	**14,711,046**
2012	12,046,280	2,142,161	101,675	**14,290,116**
2013	11,719,226	2,159,541	99,245	**13,978,011**

4.4.1.3 Uncertainties and time-series consistency (2.C.1)

The time series is consistent, since the activity data have been determined for all plants and since the same method has been used to determine the emissions for all years concerned.

Regarding CO_2 emissions from limestone inputs, a discontinuity in methods occurred from 2004 to 2005. It resulted because the data source used until 2004 was no longer available after 2004. The time-series trend seems plausible in spite of this discontinuity. In keeping with the required calculation, the uncertainty for the activity data here is ± 10%. The uncertainty is also relatively high for the activity data for the steel industry's own production of burnt lime, which production has been estimated on the basis of several assumptions. The related CO_2 emissions are comparatively insignificant, however.

The uncertainty of the emission factor for electrode consumption is ± 3 %, while the uncertainty for the other data is ± 5 %. The uncertainties are due solely to imprecision in measurement and analysis.

4.4.1.4 Category-specific quality assurance / control and verification (2.C.1)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

Determining emissions in categories 1.A.2.a and 2.C.1 is a complex task, since the Energy Balance, emissions reporting, emissions trading and association statistics differ widely in terms of their underlying methods. In the interest of data quality assurance, regular experts' discussions are carried out for the purpose of comparing and evaluating data. As a result of the methodological differences, plausibility checks of the determined emissions quantities, using data of the German emissions trading authority, are possible only at a highly aggregated level.

4.4.1.5 Category-specific recalculations (2.C.1)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.4.1.6 Planned improvements (category-specific) (2.C.1)

No further improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.4.2 *Metal production: Ferroalloys production (2.C.2)*

4.4.2.1 Category description (2.C.2)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/-	2.C.2 Ferroalloys Production	Ferro-alloys	CO_2	429.0	(0.04%)	6.1	(0.00%)	-98.6%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	IS	CS
NO_X, CO, NMVOC, SO_2			NE

The category *Ferroalloys production* is not a key category. Ferroalloys are aggregates that are alloyed with steel. There are five ferroalloy producers in Germany; ferrochromium, ferrosilicon and silicon metal are each produced by only one company, and other ferroalloys are produced only in small quantities. According to data of the British Geological Survey, in 2012, 55,374 t of ferroalloys were produced in Germany in 2007. The only process in use since 1995 is the electric arc process, a process that releases only small amounts of process-related CO_2, with such releases occurring in electrode consumption.

Until 1995, the blast-furnace process, which produces relatively higher CO_2 emissions, was used to some extent.

4.4.2.2 Methodological issues (2.C.2)

The **emission factors** for the aforementioned two processes (blast-furnace and electric-arc processes) were determined in the research project "NEW CO_2" ("NEU-CO_2") (FKZ 203 41 253/02).

For the period since 1995, the **activity data** are determined via data of the British Geological Survey (BGS). The currently available data are from 2012. The activity data have been carried forward for 2013.

4.4.2.3 Uncertainties and time-series consistency (2.C.2)

The activity data provided by the British Geological Survey (BGS) are based partly on estimates and thus are subject to relatively large uncertainties.

The relevant data of the British Geological Survey (BGS) were compared with those of the U.S. Geological Survey (USGS). While the USGS data are of the same order of magnitude as the BGS data, they are less detailed and have a higher degree of aggregation. For this reason, we have chosen to use the BGS data.

For the period 2001 – 2006, data of the Federal Statistical Office on sales of ferroalloys are available. Those data are lower, by a factor of 0.7, than the production data of the BGS, however. In the interest of the consistency of the time series, the BGS data have thus also been used for those years.

The considerable decrease in the CO_2 emission factor that took place from 1994 to 1995 does not represent any inconsistency; it is the result of the change in the production process.

4.4.2.4 Category-specific quality assurance / control and verification (2.C.2)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The activity data used, which come from the BGS, have been verified with data of the Federal Statistical Office and the USGS (see above).

4.4.2.5 Category-specific recalculations (2.C.2)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

For the current 2015 reporting round, a change was made in the data source – instead of data of the U.S. Geological Survey (USGS), data of the British Geological Survey (BGS) are now being used. The reasons for this are that the BGS data are more detailed than the USGS data and are more rapidly available each year. This change necessitates recalculations back through the year 1995.

4.4.2.6 Planned improvements (category-specific) (2.C.2)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.4.3 Metal production: Aluminium production (2.C.3)

4.4.3.1 Category description (2.C.3)

KC	Category	Activity	EM of	1990/1995 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990/1995-2013
-/T	**2.C.3 Aluminium production**		**PFC**	**1,800.7**	**(0.15%)**	**107.7**	**(0.01%)**	**-94.0%**
-/-	2.C.3 Aluminium production		CO_2	1,011.9	(0.08%)	673.1	(0.07%)	-33.5%
-/-	2.C.3 Aluminium production		SF6	11.4	(0.00%)	14.1	(0.00%)	23.7%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 3	AS	CS
CH_4	-	-	NE
PFC	Tier 3	AS	CS
NO_X	-	-	NE
CO, SO_2		AS	CS

Primary aluminium – by-product emissions

The category *Primary aluminium production* is not a key category.

In Germany, aluminium is produced at four foundries, in electrolytic furnaces with pre-burnt anodes. The principal emission sources are the waste gases from the electrolytic furnaces and fugitive emissions via the plant roofs. CO, CO_2, SO_2, CF_4 and C_2F_6 are among the most important climate-relevant substances and air pollutants that are emitted.

Production of primary aluminium continues to be the largest source of PFC emissions in Germany, in spite of the considerable reductions that have been achieved since 1990. Thanks to extensive modernisation measures in German aluminium foundries, and to decommissioning of production capacities, absolute emissions from this sector have fallen by more than 90 % since 1995. As to the future development of PFC emissions, stagnation at a low level can be expected.

Secondary aluminium – use of F gases in foundries

The category *Use of SF_6 in secondary aluminium production* (aluminium foundries) is not a key category.

Generally speaking, inert gases without additives are sufficient for rinsing secondary molten aluminium. A purification system of inert gases, with added SF_6 at a concentration of 1 or 2.5 %, has been used in the past, however, in a few – usually smaller – aluminium foundries and in laboratories. Such purification systems were last used in 1999 (no sales have taken place in Germany since 2000). From 1990 to 1999, SF_6 consumption remained relatively constant, at 0.5 t/a.

Since 1999, pure SF_6 has been used again as a purification gas, in isolated cases.

4.4.3.2 Methodological issues (2.C.3)

Primary aluminium – by-product emissions

In 2013, a total of 492,368 tonnes of primary aluminium were produced in Germany. The relevant activity data are reported annually to the Federal Environment Agency by the WirtschaftsVereinigung Metalle metal-industry association. The average anode consumption in production of primary aluminium is 430 kg of petrol coke per tonne of aluminium. Table 149 shows the process-related emission factors.

The total quantity of waste gas incurred per tonne of aluminium during the production of primary aluminium was multiplied by an average concentration value formed from several individual figures, from various different plants, with appropriate weighting. The emission factors also make allowance for fugitive emission sources, such as emissions via plant roofs. The emission figures used for CO are the results of emission measurements within the context of investment projects.

The emission factors for SO_2 and CO_2 were calculated from the specific anode consumption. The anodes consist of petrol coke; this material has specific sulphur concentrations of about 1.2 %, from which an SO_2 emission factor of 10.4 kg/t Al can be calculated. The CO_2-emission factor is calculated on the basis of the specific carbon content of petrol coke, 857 kg per t. (cf. Chapter 18.7). By multiplying the average anode consumption by the mean carbon content and carrying out stoichiometric conversion to CO_2, one obtains a CO_2-emission factor of 1367 kg/t aluminium. Theoretically, the CO_2-emission factor must be reduced by the proportion resulting from a CO fraction of 180 kg/t Al, since CO can also form only via consumption of anodes. The CO_2 factor listed below does not take this into account.

The emission factors shown in Table 149 were compared with the emission data in Best Available Techniques Reference Documents (BREF)[57] and other sources (such as VDI Guideline 2286 sheet 1).

Table 149: Activity data and process-related emission factors for primary aluminium production in 2013

	AD		Emission factors				
	Number of smelters	Production [t]	CO_2 [kg/t]	NO_X [kg/t]	SO_2 [kg/t]	C total [kg/t]	CO [kg/t]
Primary aluminium	4	492,368	1367	N. e.	10.4	N. e.	180

Emissions data are available for PFC emissions from primary aluminium smelters, thanks to a voluntary commitment on the part of the aluminium industry. Since 1997, the aluminium industry has reported annually on the development of PFC emissions from this sector. The measurement data are not published, but they are made available to the Federal Environment Agency.

The measurements conducted in all German smelters in the years 1996 and 2001 form the basis for calculation of CF_4 emissions. In this context, specific CF_4 emission figures per anode effect[58] were calculated, in keeping with the technologies used. The number of anode effects is recorded and documented in the foundries. The total CF_4 emissions were calculated by multiplying the total anode effects for the year by the specific CF_4 emissions per anode effect determined in 2001. The total emission factor for CF_4 is obtained by adding the CF_4 emissions of the smelters and then dividing the sum by the total aluminium production of the smelters. C_2F_6 and CF_4 occur in a constant ratio of about 1:10. The above-described method was applied to the time series through 2010, and the emissions for the years 1990 to 1996 were filled in via recalculations. For purposes of emissions trading, the aluminium industry has made a transition to the IAI method for calculating PFC emissions (the method is equivalent to UNFCC default Tier 2). The default slope factor used with that method is used by all other European operators, and it is accepted in the framework of European emissions trading. In the interest of consistency, as of 2010 the aluminium industry has also used the IAI method to determine emissions data for purposes of emissions reporting.

Secondary aluminium – use of F gases in foundries

For aluminium foundries, the relevant emission factor has been established more reliably, via plant-specific measurements carried out in 2010. As a result, the relevant emissions figures have been established more reliably as well.

Reports and archived survey records from 1996 have been used as a basis for the reporting years 1990 through 1994.

[57] cf. http://www.bvt.umweltbundesamt.de/kurzue.htm

58 “...Organic fluorides occur only under certain conditions, and such conditions occur in the furnace repeatedly, at intervals of hours to severals days. These conditions are referred to as the "anode effect". ... The gas at the anode changes in composition from CO_2 to CO and 5 to 20 % CF_4...." (ÖKO-RECHERCHE 1996)

Emission factor for secondary aluminium

On the basis of confidential measurement records certified by the pertinent permit authority, the SF_6 emission factor for aluminium foundries, for the period 1999 through 2008, has been reduced to 3 %. Via structural conversions, the emission factor has been further reduced, to 1.5%, as of 2009.

Activity data for secondary aluminium

SF_6-consumption data are obtained via surveys of gas sellers. At the same time, the survey for the 2000 reporting year revealed that there have been no sales of this gas mixture since 2000.

Data on the SF_6 used in pure form since 1999 have been obtained via direct surveys of users and have been compared with relevant data of gas sellers.

Since the 2007 reporting year, the data have been obtained by the *Federal Statistical Office* via surveys of gas sellers with regard to SF_6-sales figures.

4.4.3.3 Uncertainties and time-series consistency (2.C.3)

Primary aluminium – by-product emissions

The figures for PFC, CO, CO_2 and SO_2 emissions are in keeping with the Tier 3b approach and thus are considered very accurate. The time series for CO, CO_2 and SO_2 are consistent.

On the other hand, no survey of the plant-specific number of anode effects in 1991, 1992, 1993 and 1995 was conducted, in the framework of voluntary commitments, and no calculation was carried out for those years (cf. 0).

In addition, the years 1991 through 1994 were years of deep crisis for the German aluminium industry, due to sharp drops in the world-market prices for primary aluminium. For this reason, a number of plants were decommissioned. While all smelter types were affected, smelters that had recently been modernised, with point-feeder technology, were most strongly affected. Their capacity decreased by 43%, with regard to the relevant levels in 1990. This also explains the sudden increase and stagnation in the implied emission factor for CF_4 in these years. In absolute terms, the primary smelters emitted only 26 tonnes of CF_4 in 2007, while they emitted 45 tonnes in 2005. This drop was due to a decrease in production. With regard to 2006, production increased slightly, however, because partial shutdowns of furnaces in the Stade plant were more than offset by production increases at the Hamburg production site. In 2009, the economic crisis and other factors led to drastic reductions of production at the Rheinwerk Neuss site. In the period thereafter, all German primary smelters faced difficult economic situations and had to start up and shut down processes frequently, thereby incurring process instabilities. Those instabilities led to higher numbers of anode effects and, thus, to higher PFC emissions. The economic situation stabilised noticeably in 2010. That made it possible to run continuous, stable processes. As a result, the numbers of anode effects decreased to such a degree that absolute PFC emissions decreased, by comparison to their level in 2009, in spite of the production increases. That trend continued in subsequent years. In 2013, the activity data were slightly below their level in the previous year, and this manifested itself in the form of slightly higher PFC emissions.

Secondary aluminium – use of F gases in foundries

As studies have shown, part of the SF_6 used in aluminium production is broken down during such use. For the aluminium industry, the emission factor has been applied to the highest measured emissions level, and an uncertainty of 50% has been assumed for lower levels, since measurements have shown that emissions are frequently considerably lower than the maximum levels.

4.4.3.4 Category-specific quality assurance / control and verification (2.C.3)

General and category-specific quality control and quality assurance have been carried out for carbon dioxide and PFC, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

General quality control and quality assurance have been carried out for SF_6, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity. The activity data for primary aluminium production are based on surveys taken by the WirtschaftsVereinigung Metalle metal-industry association. They are reported to the Federal Environment Agency annually. The relevant time series seems plausible and shows no inconsistencies. It is assumed that such data collection conforms to quality assurance criteria.

Specific PFC emissions during anode effects were determined via industry measurements carried out in 1996 and 2001 at all plants in Germany that produce primary aluminium. In each case, the amount of PFCs produced depends on the duration and frequency of the relevant anode effects. In recent years, the duration and frequency of anode effects have been considerably reduced via computer-aided process control. In 2010, the German emission factor for CF_4, resulting from anode effects, was 0.044 kg/t aluminium. That factor is thus of the same magnitude as the average international factor, as reported by the International Aluminium Institute (IAI), of 0.034 kg/t for point-feeder systems. Therefore, the emission factor has been verified.

As to amounts consumed by Al foundries, for the 2002 reporting year, sales figures were compared for the first time with amounts used by industry, and this comparison revealed a discrepancy. That discrepancy has since been corrected. Sales figures and industrial usage quantities were compared for reporting year 2004 and showed good agreement.

4.4.3.5 Category-specific recalculations (2.C.3)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.4.3.6 Planned improvements (category-specific) (2.C.3)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.4.4 Metal production: Magnesium production (2.C.4)

4.4.4.1 Category description (2.C.4)

KC	Category	Activity	EM of	1995 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1995-2013
-/-	2.C.4 Magnesium foundries	0	SF6	176.6	(0.01%)	19.8	(0.00%)	-88.8%
-/-	2.C.4 Magnesium foundries	0	HFC 134a	0.0	(0.00%)	33.0	(0.00%)	-

Gas	Angewandte Methode	Quelle der Aktivitätsdaten	genutzte Emissionsfaktoren
SF_6	D	PS	D
HFC	D	PS	D

The category *SF_6 and HFC-134a in magnesium production* is not a key category.

No primary magnesium is produced in Germany. Only magnesium-alloy castings are produced.

In magnesium casting, since the mid-1970s, SF_6 has been used as a protective gas over molten magnesium to prevent the magnesium's oxidation and ignition. The amount of SF_6 used per tonne of magnesium (specific SF_6 coefficient) has decreased sharply from its level in 1995. This is due to the fact that HFC-134a has increasingly been used as a substitute since 2003. SF_6 is used in both a) the sand-casting process, for production of prototypes, individual parts and small series, and b) the pressure-casting process, in which it serves as a protective gas.

4.4.4.2 Methodological issues (2.C.4)

Use of SF_6 as a purification and protective gas in magnesium production is an open use, i.e. all of the SF_6 used in the process is emitted into the atmosphere. The practice of assuming the equivalence between consumption (activity data) and emissions conforms to the method in the 2006 IPCC Guidelines (Chapter 4.5).

For use of HFC-134a, the calculation method, emission factor used and figures for activity data in magnesium production are identical with the comparable figures for use of SF_6 in magnesium production.

Emission factors

For magnesium foundries, EF_{use} = 100% is assumed, due to a continuing lack of more precise decomposition-level data that would support a more precise estimate.

Activity data for magnesium production

In 1996, a survey was carried out, under commission to the Federal Environment Agency, of all domestic magnesium foundries that use SF_6. That survey determined the amounts consumed in the years 1990 to 1995.

Until the 2007 reporting year, data on the amounts used were obtained directly from users. Since the 2006 reporting year, the data have been obtained via surveys of gas sellers with regard to SF_6-sales figures. In the 2006 reporting year, the two methods were compared.

Since the 2007 reporting year, data of the *Federal Statistical Office* have been used.

4.4.4.3 Uncertainties and time-series consistency (2.C.4)

As studies have shown, part of the SF_6 used in magnesium production is broken down during such use. For this reason, the assumption that amounts used in magnesium production are emitted to a degree of 100 % probably overstates the emissions considerably. Without more precise measurements, for magnesium production, that would make it possible to determine an average degree of decomposition in the process, the uncertainties for the emission factors cannot be quantified.

4.4.4.4 Category-specific quality assurance / control and verification (2.C.4)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

Quality assurance / control for amounts consumed in Mg foundries was carried out via a one-time comparison of findings from foundry surveys with producers' total SF_6 sales figures – and with data of gas sellers. For the 2007 report year, additional findings resulting from a technical discussion held in December 2007 have been taken into account.

4.4.4.5 Category-specific recalculations (2.C.4)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.4.4.6 Planned improvements (category-specific) (2.C.4)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.4.5 Metal production: Lead (2.C.5)

4.4.5.1 Category description (2.C.5)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/-	2.C.5 Lead production		CO_2	151.5	(0.01%)	88.1	(0.01%)	-41.9%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1	AS	D/CS

The category *Metal production*: *Lead* is not a key category.

In Germany, lead is produced from primary lead concentrates and secondary raw materials such as lead-containing scrap and lead acid batteries.

All primary lead production in Germany takes place via the direct smelting (DS) process, either in bath smelting furnaces (Isasmelt-Ausmelt) or in QSL reactors. Process-related CO_2 emissions occur primarily via addition of carbon-containing reducing agents (such as coal dust). The imperial smelting (ISF) process is no longer used in Germany.

Recycling of lead acid batteries is the key factor shaping secondary lead production in Germany. The relevant sector uses both short rotary furnaces and shaft furnaces. Process-related CO_2 emissions occur primarily via addition of carbon-containing reducing agents (for example, coke).

In 2013, a total of 400,325 tonnes of lead were produced in Germany. The relevant activity data are reported annually to the Federal Environment Agency by the WirtschaftsVereinigung Metalle metal-industry association.

4.4.5.2 Methodological issues (2.C.5)

The **emission factors** that have been used have been taken from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (the values in Table 4.21). All primary lead production in Germany takes place via the direct smelting (DS) process. A separate process is used for secondary lead production (S). The DS/S production-quantity ratio in Germany is relatively constant, at about 1/ 1.5. The emission factor of 220 kg CO_2 / t lead was obtained by applying that ratio to the values in Table 4.21:

$$EF_{lead} = \frac{DS \cdot EF_{DS} + S \cdot EF_S}{DS + S} = \frac{1 \cdot 0{,}25\ \frac{t\ CO2}{t\ lead} + 1{,}5 \cdot 0{,}2\ \frac{t\ CO2}{t\ lead}}{2{,}5} = 0{,}22\ \frac{t\ CO2}{t\ lead}$$

DS: Quantity of primary lead produced using the direct smelting process
S: Quantity of secondary lead produced
DS/S: This production-quantity ratio is relatively constant in Germany, at 1/1.5
EF_{lead}: Overall CO_2-emission factor for lead
EF_{DS}: CO_2 emission factor for the direct smelting process as used in primary lead production – 0.25 t CO_2 / lead (pursuant to Table 4.21)
EF_S: CO_2 emission factor for secondary lead production – 0.20 t CO_2 / lead (pursuant to Table 4.21)

4.4.5.3 Uncertainties and time-series consistency (2.C.5)

The uncertainties are in keeping with the Tier 1 method.

4.4.5.4 Category-specific recalculations (2.C.5)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.4.5.5 Category-specific quality assurance / control and verification (2.C.5)

The activity data are based on confidential surveys taken by the WirtschaftsVereinigung Metalle metal-industry association. They are reported to the Federal Environment Agency annually. The relevant time series seems plausible and shows no inconsistencies. It is assumed that such data collection conforms to quality assurance criteria.

4.4.5.6 Category-specific planned improvements (2.C.5)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.4.6 Metal production: Zinc (2.C.6)

4.4.6.1 Category description (2.C.6)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/-	2.C.6 Zinc production		CO_2	670.8	(0.06%)	279.0	(0.03%)	-58.4%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1	AS	D

The category *Metal production*: *Zinc* is not a key category.

In Germany, zinc is produced from primary zinc concentrates and secondary raw materials such as zinc-containing scrap and steel mill dust.

All primary zinc production in Germany takes place via the hydrometallurgical process. The imperial smelting process, a pyrometallurgical process, is not used.

In this sector in Germany, process-related greenhouse-gas emissions occur primarily in secondary zinc production. Process-related CO_2 emissions occur via use of coke as a reducing agent, especially in processing of zinc-containing secondary materials in rotary kilns.

In 2013, a total of 162,231 tonnes of zinc were produced in Germany. The relevant activity data are reported annually to the Federal Environment Agency by the WirtschaftsVereinigung Metalle metal-industry association.

4.4.6.2 Methodological issues (2.C.6)

The **emission factors** used have been taken from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (default factors), since no better figures are currently available.

4.4.6.3 Uncertainties and time-series consistency (2.C.6)

The uncertainties are in keeping with the Tier 1 method.

4.4.6.4 Category-specific recalculations (2.C.6)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.4.6.5 Category-specific quality assurance / control and verification (2.C.6)

The activity data are based on confidential surveys taken by the WirtschaftsVereinigung Metalle metal-industry association. They are reported to the Federal Environment Agency annually. The relevant time series seems plausible and shows no inconsistencies. It is assumed that such data collection conforms to quality assurance criteria.

4.4.6.6 Category-specific planned improvements (2.C.6)

Specific data for determination of emission factors will be collected in the next rounds of reporting.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.4.7 Metal production: Other (2.C.7)

No emissions are reported in category 2.C.7.

4.4.7.1 Category description (2.C.7)

In Germany, this category primarily includes copper production. The majority of that industry's greenhouse-gas emissions occur in process combustion; those emissions are reported under 1.A.2.b. The greenhouse-gas emissions that do not originate in process combustion are very low by comparison.

4.4.7.2 Methodological issues (2.C.7)

No emission factors are available. In addition, the 2006 IPCC Guidelines for National Greenhouse Gas Inventories provide no pertinent default factor.

4.4.7.3 Uncertainties and time-series consistency (2.C.7)

No information.

4.4.7.4 Category-specific recalculations (2.C.7)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.4.7.5 Category-specific quality assurance / control and verification (2.C.7)

The activity data are based on confidential surveys taken by the WirtschaftsVereinigung Metalle metal-industry association. They are reported to the Federal Environment Agency annually. The relevant time series seems plausible and shows no inconsistencies. It is assumed that such data collection conforms to quality assurance criteria.

4.4.7.6 Category-specific planned improvements (2.C.7)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.5 Non-energy-related products from fuels and solvents (2.D)

4.5.1 Lubricant use (2.D.1)

4.5.1.1 Category description (2.D.1)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/-	2.D.1 Lubricant use		CO_2	522.8	(0.04%)	569.9	(0.06%)	9.0%

Gas	Angewandte Methode	Quelle der Aktivitätsdaten	genutzte Emissionsfaktoren
CO_2	Tier 1	NS	D

The category *Lubricant use* is not a key category for CO_2 emissions.

Lubricants are used to reduce friction and wear in moving machine parts. They can also be used for transmission of power and heat. Furthermore, lubricants are used as sealants, and they are used to prevent build-up of deposits and to guard against corrosion. Consequently, special lubricants have been developed for many specific applications. The consumption of lubricants in Germany has remained at a relatively constant level since 1990, apart from a sharp decrease in 2009 that was related to the overall economic situation.

4.5.1.2 Methodological issues (2.D.1)

Lubricant use has been divided into the two major areas of use in motor vehicles, including other mobile sources, and use in industry; this is due to different calculation methods involved.

The German greenhouse-gas inventory covers CO_2 emissions from co-combustion of lubricants for all mobile sources. In keeping with emissions reporting requirements, emissions from two-stroke petrol engines are allocated directly to the pertinent emission sources, since in those cases lubricants are seen as part of the relevant fuels (fuel mixtures for two-stroke engines). On the other hand, all co-combustion emissions that are not caused by two-stroke engines are considered to result from product use and are reported in the present section, along with emissions from lubricant use in industrial sectors. The relevant calculation method is described here and in 19.1.4.

Activity data – lubricant use in industry

The activity data used for lubricant use in industry consist of the domestic-sales data as listed in the statistics in the "Official Mineral Oil Statistics for the Federal Republic of Germany" ("Amtliche Mineralöldaten für die Bundesrepublik Deutschland") of the Federal Office of Economics and Export Control (BAFA) (Table 10j).

Emission factors – lubricant use in industry

The CO_2 emissions are calculated via a Tier 1 method. The emission factor, which has been applied to the entire time series, was derived on the basis of the standard values in the 2006 IPCC Guidelines (IPCC-GL2006, Vol. 3 Chapter 5, including Table 5.2).

4.5.1.3 Uncertainties and time-series consistency (2.D.1)

A Tier 1 method and standard values from the 2006 IPCC Guidelines have been used, and thus that source's relevant uncertainties for the activity data and emission factors apply (2006 IPCC Guidelines, Volume 3, Chapter 5).

4.5.1.4 Category-specific recalculations (2.D.1)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.5.1.5 Category-specific quality assurance / control and verification (2.D.1)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

4.5.1.6 Category-specific planned improvements (2.D.1)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.5.2 Paraffin wax use (2.D.2)

4.5.2.1 Category description (2.D.2)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/-	2.D.2 Paraffin wax use		CO_2	248.4	(0.02%)	650.0	(0.07%)	161.7%
-/-	2.D.2 Paraffin wax use		N_2O	0.6	(0.00%)	1.6	(0.00%)	161.7%

Gas	Angewandte Methode	Quelle der Aktivitätsdaten	genutzte Emissionsfaktoren
CO_2	Tier 1	NS	D
N_2O	Tier 1	NS	D

The category *Paraffin wax use* is not a key category for CO_2 and N_2O emissions.

Within the European Union, Germany is an important market for candles. In 2013, its share of the market amounted to 35 % ("Verbrauch von Kerzen in der Europäischen Union (EU28)" ("consumption of candles in the European Union (EU28)") of the European Candle Association ASBL) In contrast to the overall European trend, candle consumption grew continually in Germany from 1990 through 2013. Production has remained at a constant level, and the country's growing additional requirements are being met via imports.

4.5.2.2 Methodological issues (2.D.2)

The calculation model is based on the assumption that all candles are consumed within a year of their purchase and are burned completely.

The CO_2 and N_2O emissions are calculated via a Tier 1 method.

Activity data

The data on candle production, and on the imported and exported quantities, for the years 1996 through 2013, were obtained from the Federal Statistical Office (STATISTISCHES BUNDESAMT, Fachserie 4, Reihe 3.1, Produzierendes Gewerbe, Produktion im Produzierenden Gewerbe sowie der Außenhandelsstatistik ("manufacturing industry; production in the manufacturing industry and foreign-trade statistics").

The quantities consumed are calculated in keeping with the formula Production + Imports – Exports.

For the years 1990 through 1995, the quantities consumed are calculated from the per-capita consumption, which has been derived from the data for the years 1996 through 2013. In the process, it is assumed that consumption also grew linearly in those (earlier) years.

Emission factors

The emission factor for CO_2 is 2.9467 t/t product; for N_2O, the factor is 0.024 kg/t product.

The emission factors were derived on the basis of standard values (IPCC-GL2006, Vol. 2, Chapter 1, Table 1.2, and IPCC-GL2006, Vol. 2, Chapter 2, Table 2.4)

4.5.2.3 Uncertainties and time-series consistency (2.D.2)

A Tier 1 method and standard values from the 2006 IPCC Guidelines have been used, and thus that source's relevant uncertainties for the activity data and emission factors apply (2006 IPCC Guidelines, Volume 3, Chapter 5).

4.5.2.4 Category-specific recalculations (2.D.2)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.5.2.5 Category-specific quality assurance / control and verification (2.D.2)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

4.5.2.6 Category-specific planned improvements (2.D.2)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.5.3 Other: Solvents – NMVOC (2.D.3)

4.5.3.1 Category description (2.D.3)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/-	2.D.3 Other	0	CO_2	2,552.0	(0.21%)	1,401.4	(0.15%)	-45.1%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	D	NS	D
NMVOC	Tier 2	NS	CS

The category indirect CO_2 from NMVOC emissions, within the category *Solvent and other product use* (CRF 2.D.3), is not a key category, due to its inclusion within the overarching category *2.D.3 – Other*.

The NMVOC emissions released through use of solvents and solvent-containing products all belong to sub-categories of this category.

The four reporting categories of this category vary widely in structure. To take account of this variation, inventory data were calculated in keeping with the UNECE/EMEP sub-structures based on the CORINAIR97 (CORINAIR: COordination d' INformation Environmentale; sub-project AIR) SNAP system[59].

Category 2.D.3 *4. Other: Solvents – NMVOC* includes the following applications and activities:

- Treatment of glass and rock wool

[59] In the present area, this involves "SNAP Level 3" detailing.

- Printing industry (printing applications)
- Extraction of oils and fats
- Use of glues and adhesives
- Use of wood preservatives
- Undersealing and wax treatments for automobiles
- Household use of solvents (not including paints and lacquers)
- Automobile-wax stripping
- Manufacturing of pharmaceutical products
- Household use of pharmaceutical products
- Other

"NMVOC" is defined in keeping with the VOC definition found in the EC solvents directive[60]. For purposes of the definition of solvents, the term "solvent use" is also defined in keeping with the EC solvents directive[61].

It is important to note that some volatile organic compounds are used both as solvents and as chemical reactants – for example, toluene, which is used as a solvent in lacquers and glues and as a reactant for production of toluenediisocyanate (TDI), and methyl ethyl ketone (butanone), which is used as a solvent in printing inks and as a base material for synthesis of methyl ethyl ketone peroxide. Consequently, VOC (either substances or fractions of substances or products) used as chemical reaction components are not included in this category.

Delimitation of this category as outlined above takes a highly diverse range of emissions-causing processes into account. The factors considered with regard to such processes include:

- Concentrations and volatility of VOC used.
  The relevant spectrum includes use of volatile individual substances as solvents – for example, in cleansing; use of products with solvent mixtures – for example, in paints and lacquers; and applications in which only small parts of mixtures used (also) have solvent properties (as is the case, for example, in polystyrene-foam production).
- The great differences in emissions conditions.

Solvent uses can be open to the environment – as is the case in use of cosmetics – or largely closed to the environment – as in extraction of essential oils or cleaning in chemical dry-cleaning systems.

4.5.3.2 Methodological issues (2.D.3)

NMVOC emissions are calculated via an approach oriented to product consumption. In this approach, the NMVOC input quantities allocated to these categories, via solvents or solvent-containing products, are determined and then the relevant NMVOC emissions (for each category) are calculated from those quantities via specific emission factors. This method is explicitly listed, under "consumption-based emissions estimating", as one of two methods that are to be used for emissions calculation for this category.

[60] In this definition, volatile organic compounds (VOC) include all organic compounds that are volatile at 293.15 K, at a vapour pressure of at least 0.01 kPa or under the usual conditions for their use.

[61] In this definition, an organic solvent is a volatile organic compound that, either by itself or in combination with other raw materials, products or waste substances, and without changing chemically, either dissolves or is used as a cleanser for dissolving dirt accumulations, as a solvent, as a dispersing agent, as an agent for adjusting viscosity or surface tension, or as a softener or preservative.

Use of this method is possible only with valid input figures – differentiated by categories – in the following areas:

- the quantities of VOC-containing (pre-) products and agents used in the report year,
- the VOC concentrations in these products (substances and preparations),
- the relevant application and emission conditions (or the resulting specific emission factor).

To take account of the highly diverse structures throughout this category, these input figures are determined on the level of 37 differentiated categories (in a manner similar to that used for CORINAIR SNAP Level 3), and the calculated NMVOC emissions are then aggregated. The product / substance quantities used are determined at the product-group level with the help of production and foreign-trade statistics. Where possible, the so-determined domestic-consumption quantities are then further verified via cross-checking with industry statistics.

The values used for the average VOC concentrations of the input substances, and the emission factors used, are based on experts' assessments (expert opinions and industry dialogues) relative to the various categories and category areas. Not all of the necessary basic statistical data required for calculation of NMVOC emissions for the most current relevant year are available in final form; as a result, the data determined for the previous year are used as a basis for a forecast for the current report. The forecast for NMVOC emissions from solvent use for the relevant most current year is calculated on the basis of specific activity trends. As soon as the relevant basic statistical data are available for the relevant most current year, in their final form, the inventory data for NMVOC emissions from solvent use are recalculated.

Since 1990, NMVOC emissions from use of solvents and solvent-containing products have decreased by nearly 44 %. The greatest part of this emissions reduction has occurred in the years since 1999. This successful reduction has occurred especially as a result of regulatory provisions such as the Ordinance, under chemicals law, for limiting emissions of volatile organic compounds (VOC) through limitations on the placing on the market of solvent-containing paints and varnishes *(Chemikalienrechtliche Verordnung zur Begrenzung der Emissionen flüchtiger organischer Verbindungen (VOC) durch Beschränkung des Inverkehrbringens lösemittelhaltiger Farben und Lacke (Lösemittelhaltige Farben- und Lack-Verordnung – ChemVOCFarbV)*, the 31st Ordinance on the Implementation of the Federal Immissions Control Act (Ordinance on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain facilities – 31. *BImSchV)*, the 2nd such ordinance *(Ordinance on the limitation of emissions of highly volatile halogenated organic compounds* – 2. *BImSchV)* and the Technical Instructions on Air Quality Control (TA Luft). The German "Blauer Engel" ("Blue Angel") environmental quality seal, which is used to certify a range of products, including paints, lacquers and glues with low solvent concentrations, has also played an important role in this development.

While product sales increased in some areas – even over periods of several years – thereby adding to emissions, the above-described measures have largely offset this trend. These successes, which have occurred especially in recent years, are reflected in the updated emissions calculations – which, thanks to methods optimisation, now feature greater differentiation of VOC concentrations and emission factors.

Since the 2009 report, indirect CO_2 emissions are calculated from NMVOC.

Since compatibility with EU greenhouse-gas reporting is the primary methodological backdrop for conversion of NMVOC emissions into indirect CO_2 emissions, for the current report we have used the Reference Approach proposed in *Chapter 7 Precursors and Indirect Emissions* of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories:

$$EM_{Indirect\ CO2} = EM_{NMVOC} * \text{molar mass } CO_2 / \text{molar mass C} * 60\ \%$$

In the framework of an expert assessment, and with the help of technical discussions with the affected sectors in 2013, the solvent content levels of various paints and coatings have been adapted to the current state of the art – and, thus, reduced. Via category-specific recalculations, this has led to emissions adjustments for the years 2010 and 2011. In the category Coating application, in particular, we calculated an emissions reduction for the years 2010 and 2011, with respect to the last Submission (cf. Chapter 4.5.3.5).

4.5.3.3 Uncertainties and time-series consistency (2.D.3)

At the time of the report, errors had been estimated for NMVOC emissions; this was carried out using the error-propagation method and on the basis of experts' assessments for all input figures (in all 37 differentiated categories). The main source of current uncertainties consists of inadequate precision in separation of basic statistics (production and foreign-trade statistics), with regard to categorisation in VOC-containing and VOC-free products, and with regard to use in different categories with highly differing emissions conditions.

4.5.3.4 Category-specific quality assurance / control and verification (2.D.3)

Due to resources limitations, and to the area's minimal relevance, no QC/QA is carried out for reporting relative to precursors.

4.5.3.5 Category-specific recalculations (2.D.3)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.5.3.6 Category-specific planned improvements (2.D.3)

No further improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.5.4 Mineral Products: Bitumen for roofing (2.D.3 Other, bitumen)

Gas	Method used	Source for the activity data	Emission factors used
NMVOC	Tier 1	AS	CS

As far as is currently known, the category *Bitumen for roofing* produces no greenhouse-gas emissions[62] and thus is not a key category.

[62] Cf. the discussion of indirect CO_2 emissions, under "Methodological aspects".

4.5.4.1 Category description (2.D.3 Other, bitumen)

Bitumen is used in production and laying of roof and sealing sheeting.

The quantities of roof and sealing sheeting that are produced and used in Germany are shown in Table 150. The discrepancy between the two figures (production and use) is due to an export surplus. In such production, liquid bitumen is applied, at temperatures of 150°C to 220°C, as a saturating or coating agent. This process produces emissions of organic substances (combined here as NMVOC).

Roof and sealing sheeting is laid by means of both hot and cold processes. The hot process, involving welding of sheeting, produces significant emissions of organic substances. The relevant emissions trends depend primarily on trends in quantities of polymer bitumen sheeting produced. Use of solvent-containing primers is not considered here; it is covered via the solvents model – cf. Chapter 4.5.1.

Emissions from production of roof and sealing sheeting have been decreasing slightly, in keeping with decreasing production quantities. Emissions from laying of roof and sealing sheeting have remained about the same, although the quantities used have been decreasing.

Substances other than NMVOC are of only subordinate relevance in terms of emissions (cf. footnote [62])).

4.5.4.2 Methodological aspects (2.D.3 Other, bitumen)

Data on quantities of roof and sealing sheeting that are produced and used (**activity data**) are provided by the VDD association of the bitumen, roof sheeting and sealing sheeting industry (VDD, 2014), on the basis of a cooperation agreement dating from 2009. At present, no data supplementation or extrapolation is being carried out. To obtain internationally comparable figures, production quantities are converted into quantities of input bitumen (the conversion relationship, depending on the type of sheeting concerned, varies from 1.3 to 3.3 bitumen kg/m^2).

Because of their predominating importance, only NMVOC emissions are considered and taken into account in the emissions inventory. In the process, a distinction is made between emissions from production and emissions from laying of roof and sealing sheeting.

The **emission factor** for production of roof and sealing sheeting was obtained via a calculation in accordance with current technological standards of German manufacturers (VDD, 2009). The emission factor for laying of polymer bitumen sheeting has been taken from an ecological balance sheet (IKP, 1996). That emission factor has also been adopted, by analogy, for sheeting glued primarily with hot bitumen. Thin sheeting is not glued; it is attached via nailing and produces no emissions. The implied emission factor for the category has been increasing slightly, as a result of the increasing importance of polymer bitumen sheeting.

NMVOC emissions are calculated in keeping with a Tier 1 method, since no pertinent detailed data are available.

Table 150: Production and laying of roof and sealing sheeting with bitumen, and relevant activity data and emission factors

	Produced or used area in 2013 [millions of m^2]	EF/ IEF [kg/ m^2]
Production of roof and sealing sheeting with bitumen	163	NMVOC 0.00035795
Laying of roof and sealing sheeting with bitumen	138	NMVOC 0.000027 – 0.000040

The carbon dioxide emissions, which could be obtained by multiplying the NMVOC emissions by a carbon-content factor of 80% and then converting to CO_2, are negligible. For this reason, they are not listed as such; in the CRF tables, they are marked as "NE".

4.5.4.3 Uncertainties and time-series consistency (2.D.3 Other, bitumen)

Information relative to the uncertainty of the data of the VDD was obtained via consultation between the VDD and the Federal Environment Agency. The total uncertainty for the activity data for production and laying of sheeting is estimated to be about +/-1 %. That figure, in turn, leads to a higher uncertainty, of about +/-2.5 %, for the calculated bitumen consumption.

The uncertainty for the combined emission factors for production and laying of roof and sealing sheeting is estimated to be about +/-5 %.

4.5.4.4 Category-specific quality assurance / control and verification (2.D.3 Other, bitumen)

Due to resources limitations, and to the area's minimal relevance, no QC/QA is carried out for reporting relative to precursors. A QC/QA checklist was completed and confirmed in the framework of the agreement with the VDD.

The manner in which the activity data were determined is considered to be plausible. The emission factors accord with findings from pertinent Federal Environment Agency research projects and are plausible. In particular, the validity of the emission factors is justified in that no emissions from use of solvent-containing coatings and primers have to be taken into account in this section (that takes place in the solvents model, as noted above).

4.5.4.5 Category-specific recalculations (2.D.3 Other, bitumen)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.5.4.6 Category-specific planned improvements (2.D.3 Other, bitumen)

No further improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.5.5 Mineral Products: Road paving with asphalt (2.D.3 Other, asphalt)

Gas	Angewandte Methode	Quelle der Aktivitätsdaten	genutzte Emissionsfaktoren
NO_X, NMVOC, SO_2	Tier 1	AS	CS
CO_2	NE	NE	NE

Die As far as is currently known, the category "Road paving with asphalt" produces no greenhouse-gas emissions[63] and thus is not a key category.

4.5.5.1 Category description (2.D.3 Other, asphalt)

Currently, the report tables list produced quantities of mixed asphalt products and NMVOC, NO_X and SO_2 emissions (with regard to CO_2, cf. footnote 63).

In 2013, a total of about 41 million t of asphalt (DAV, 2014) was produced in Germany, in a total of more than 600 asphalt-mixing plants. Asphalt is used primarily in road construction, where it competes directly with hydraulically bound concrete. In 1991, total production increased considerably; since 2000 it has been decreasing again.

The relevant emissions trends depend primarily on trends in production quantities. In 2012, the production quantity sank to the lowest level ever seen in unified Germany. That low production level, which persisted in 2013, is the result of a lack of investments in the country's road network.

4.5.5.2 Methodological aspects (2.D.3 Other, asphalt)

No special calculation procedure is available for calculating fuel inputs in category 1.A.2. Nonetheless, fuel inputs are taken into account via Energy Balance evaluation, and they are coupled with suitable emission factors.

The applicable quantity of mixed asphalt products produced (**activity data**) has been taken from communications of the Deutscher Asphaltverband (DAV; German asphalt association).

The **emission factors** were determined country-specifically, in accordance with Tier 2 criteria. Emission factors for substances other than CO_2 were determined on the basis of emissions measurements for over 400 asphalt-mixing plants, for the period 1989 to 2000. The majority of the emissions occur during drying of pertinent mineral substances. Almost all of the NMVOC emissions originate in the organic raw materials used, and they are released primarily in parallel-drum operation, as well as from mixers and loading areas. On average, about 50% of the NO_X and SO_2 involved come from the mineral substances used (proportional process emissions). CO occurs primarily in incomplete combustion processes. CO emissions are calculated solely in connection with fuel inputs.

Table 151: Emission factors for production of mixed asphalt products

	NOx	NMVOC	SO_2
EF [kg/ t]	0.015	0.030	0.030

Only emissions from asphalt production are reported. Figures relative to emissions released during laying of asphalt have not yet been adequately reviewed.

[63] Cf. the discussion of indirect CO_2 emissions, under "Methodological aspects".

The carbon dioxide emissions, which could be obtained by multiplying the NMVOC emissions by a carbon-content factor of 80 % and then converting to CO_2, are negligible. For this reason, they are not listed as such; in the CRF tables, they are marked as "NE".

4.5.5.3 Uncertainties and time-series consistency (2.D.3 Other, asphalt)

As the extensive measurement data show, the emissions lie within a comparatively narrow range. The large volume of measurement data available makes it possible to form highly reliable mean values. The only large uncertainties are found in breakdown of emissions amounts into fuel-related and process-related emissions.

The production-amount data may be considered very accurate, since the product in question is a sale-ready product, and operators report the relevant amounts to the DAV.

4.5.5.4 Category-specific quality assurance / control and verification (2.D.3 Other, asphalt)

Due to resources limitations, and to the area's minimal relevance, no QC/QA is carried out for reporting relative to precursors.

4.5.5.5 Category-specific recalculations (2.D.3 Other, asphalt)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.5.5.6 Category-specific planned improvements (2.D.3 Other, asphalt)

No further improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.6 Electronics industry (2.E)

KC	Category	Activity	EM of	1995 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1995-2013
-/-	2.E. Electronics industry		PFC	265,1	(0,02%)	139,7	(0,01%)	-47,3%
-/-	2.E Electronics industry		SF6	47,3	(0,00%)	18,6	(0,00%)	-60,7%
-/-	2.E. Electronics industry		HFC	17,1	(0,00%)	13,6	(0,00%)	-20,6%
-/-	2.E Electronics industry		NF3	5,3	(0,00%)	16,7	(0,00%)	216,1%

Gas	Angewandte Methode	Quelle der Aktivitätsdaten	genutzte Emissionsfaktoren
HFC	Tier 3	AS, NS	PS
PFC	D, Tier 3	AS, NS	CS, PS
SF6	D, Tier 3	AS, NS	CS, PS
NF3	D, Tier 3	AS, NS	CS, PS

The category *Electronics industry* is not a key category.

4.6.1 Semiconductor and circuit-board production (2.E.1)

4.6.1.1 Category description (2.E.1)

The semiconductor industry currently emits PFCs (CF_4, C_2F_6, C_3F_8, c-C_4F_8), HFCs (CHF_3), nitrogen trifluoride (NF_3) and SF_6 from production processes. These gases are used for etching structures on thin layers and for cleaning reaction chambers following chemical vapour deposition (CVD). In the production process, some of the PFCs fed into plasma chambers are converted partly into CF_4.

The semiconductor industry's emissions depend partly on the degree to which the industry uses waste-gas-scrubbing equipment. They also depend directly on semiconductor-production levels (in the present case, annual levels). As a result of these dependencies, emissions tend to fluctuate rather strongly from year to year.

4.6.1.2 Methodological issues (2.E.1)

Emission factors

During the etching process, only about 15 % of the added CF_4 reacts chemically. The emission factor, an inverse reaction quota, thus amounts to 85 % of the CF_4 consumption.

The emissions cannot be determined solely on the basis of input quantities (sales by gas vendors), however, because the difference between consumption and emissions depends on a number of factors – especially the effects of downstream waste-gas-scrubbing systems, in addition to only-partial chemical transformation in plasma reactors. The relevant figures are thus aggregated and reported on a plant-specific basis, by the pertinent industrial association.

Activity data

Reliable emissions data are available for 1990 and 1995. Linear interpolation was carried out for the years 1991 to 1994.

Until the 2000 report year, emissions data were based on surveys carried out by the EECA-ESIA (European Electronic Component Manufacturers Association – European Semiconductor Industry Association). National manufacturers were queried regarding production capacities, amounts of substances used and waste-gas treatment equipment.

As the result of a voluntary commitment by the semiconductor industry, emissions figures are available for this sub- category, for all individual substances, from the year 2001 onwards. In keeping with a standardised calculation formula (Tier 2c approach), the emissions data are calculated for each production site, from annual consumption, aggregated and then reported by the German Electrical and Electronic Manufacturers Association (Zentralverband Elektrotechnik- und Elektroindustrie eV. – ZVEI, electronic components and systems) to the Federal Environment Agency.

4.6.1.3 Uncertainties and time-series consistency (2.E.1)

The uncertainties have been completely determined.

4.6.1.4 Category-specific recalculations (2.E.1)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.6.1.5 Category-specific quality assurance / control and verification (2.E.1)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The data have undergone the above association's internal quality assurance and quality control process.

Quality control (pursuant to Tier 1) and quality assurance, in conformance with the requirements of the QSE manual and its associated applicable documents, have been carried out.

4.6.1.6 Category-specific planned improvements (2.E.1)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.6.2 TFT (2.E.2)

No TFT flat screens are produced in Germany.

4.6.3 Photovoltaics (2.E.3)

4.6.3.1 Category description (2.E.3)

In wafer production in Germany, SF_6 and other fluorine compounds are used for structure etching and for cleaning of reaction chambers during production processes. Since the purity of the process gas is lower than that of the gas used in the similar production process in the semiconductor industry, use for *photovoltaics* is reported separately. In Germany, use of SF_6 in solar technology began in 2002.

The time series shows a continuous emissions increase between 2002 and 2006; this is due to increases in production. A large jump occurred in 2007 and 2008, when quantities of produced wafers and, thus, the quantities of SF_6 used, increased sharply. In 2009, the opposite effect occurred.

Since 2008, NF_3 has substituted for SF_6 in all new production lines for production of Si thin-film cells.

In addition, in 2002/2003 the hydrocarbon CF_4 was introduced for "edge insulation" of crystalline solar cells. The procedure using that substance was soon supplanted by a different procedure that is easier to handle, however. Consumption of CF_4, which peaked in 2004, has been decreasing sharply since then.

4.6.3.2 Methodological issues (2.E.3)

Like emissions in the semiconductor industry, emissions in photovoltaics occur during production. The relevant production emissions cannot be determined solely on the basis of the quantities used (sales by the gas trade). The differences between consumption and emissions result from a) the fact that chemical conversion in plasma reactors is only partial and b) the effects of downstream waste-gas-scrubbing systems.

Emission factors

In 2009, only one producer in Germany did not have a waste-gas-scrubbing system. For this reason, the IPCC emission factor of 40 % is used only for the first year of pertinent use, 2003. Thereafter, the emission factor decreases, as the percentage of wafer production connected to downstream waste-gas-scrubbing systems increases. In 2010, it was just under 6 %. Since then, it has dropped to 4 %.

Activity data

The annual consumption figures are obtained via surveys, carried out by the Federal Statistical Office, of gas suppliers, with regard to their domestic sales. In addition, the data were checked in a separate study entitled "SF_6 and NF_3 in the German photovoltaic industry" ("SF_6 und NF_3 in der deutschen Photovoltaik-Industrie") (ÖKO-RECHERCHE, 2009: FKZ 360 16 027).

4.6.3.3 Uncertainties and time-series consistency (2.E.3)

The uncertainties have been completely determined.

4.6.3.4 Category-specific recalculations (2.E.3)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.6.3.5 Category-specific quality assurance / control and verification (2.E.3)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

4.6.3.6 Category-specific planned improvements (2.E.3)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.6.4 Heat transfer fluids (2.E.4)

In the semiconductor industry, the PFC C_6F_{14} is used as a heat transfer fluid. In response to enquiries, the industry has disclosed that 5 kg of this substance (46.5t CO_2 equivalents) were used in 2013. The greenhouse-gas emissions from this category thus amount to less than 0.05 % of the total inventory (not including LULUCF), and they are less than 500 kt CO_2-equivalents. What is more, relevant annual surveys cannot be assured (pursuant to FCCC/SBSTA/2013/L.29/Add.1, para 37). For this reason, we refrain from reporting on this area (IPCC, 2006d). The present chapter thus presents a one-time quantitative estimation of the emissions that are not covered by the inventory as a result. In addition, a compilation of all sources listed as "not estimated" is presented in Annex 5 in Chapter 21 of the present report.

4.7 Product uses as substitutes for ODS (2.F)

KC	Category	Activity	EM of	1995 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1995-2013
L/T	**2.F Product uses as substitutes for ODS**		**HFC**	**2,580.3**	**(0.21%)**	**10,514.0**	**(1.12%)**	**307.5%**
-/-	2.F Product uses as substitutes for ODS		PFC	19.9	(0.00%)	9.4	(0.00%)	-52.8%

Gas	Method used	Source for the activity data	Emission factors used
HFC, PFC, SF_6	cf. Table 152/Table 153	cf. Table 152/Table 153	cf. Table 152/Table 153

The category Product uses as substitutes for ODS is a key category for HFC emissions in terms of emissions level and trend.

Category 2.F includes Refrigeration and air conditioning systems (2.F.1), Foam blowing (2.F.2), Fire extinguishing agents (2.F.3), Aerosols (2.F.4), Solvents (2.F.5) and other applications; ODS substitutes fall under (2.F.6). In the interest of more precise data collection, these sub-categories are broken down further, as described in the following sub-chapters.

Use of relevant substances as refrigerants in stationary and mobile refrigeration applications, which accounts for over three-fourths of relevant emissions, is the largest source of HFC emissions in this category. The remaining emissions are distributed among the sources foams and aerosols and, in small amounts, fire extinguishers and solvents.

The PFC emissions originate in use of refrigerant blends in refrigeration and air-conditioning systems.

Table 152: Overview of methods and emission factors used for the current reporting year, in category 2.F - *Consumption of HFCs, PFCs and SF_6*.

	QG	Method	Gas		Lifetime	Production	Application	Waste management	
			HFC	PFC	[years]	Emission factor (dimensionless)	Emission factor (dimensionless)	Residual charge level (dimensionless)	Recovery rate (dimensionless)
1. Air-conditioning and refrigeration systems	**2.F.1**								
Commercial refrigeration	2.F.1a								
- Plug-in appliances		Tier 2a	HFC		10 (D)	0.005 (D)	0.01 - 0.014 (D)	0.90 (CS)	0.326 - 0.460 (D)
- Condensing units					12 (D)	0.01 (D)	0.064 - 0.097 (CS)	0.85 (D)	0.475 - 0.66 (D)
- Central systems				PFC	14 (D)	0.01 (D)	0.105 - 0.195 (D)	0.875 (D)	0.429 - 0.760 (D, CS)
Household refrigeration	2.F.1b	Tier 2a	HFC		15 (D)	NO	0.003 (D)	0.955 (CS)	0.733 (CS)
Industrial refrigeration	2.F.1c								
- Plug-in appliances		Tier 2a	HFC		10 (CS)	0.005 (D)	0.01 - 0.014 (CS)	0.9 (D)	0.337 – 0.460(D)
- Large refrigeration systems				PFC	10 – 30 (CS, D)	0.01 (D)	0.059 - 0.088 (D)	0.85 (D)	0.45 – 0.765(D)
Refrigerated transports	2.F.1d								
- Refrigerated vehicles		Tier 2a	HFC	PFC	10 (CS)	5 g/system (CS, D)	0.15 - 0.3 (D)	0.875 (CS)	0.657 (D)
- Refrigerated containers					14 (CS)	NO	0.1 (CS)	0.875 (CS)	0.657 (D)
Mobile air conditioning systems	2.F.1e								
- Trucks		Tier 2a	HFC		15 (D)	5 g/system (CS, D)	0.15 (D)	0.34 (D)	0.38 - 0.407 (D)
- Automobiles					15 (D)	3 g/system (CS, D)	0.1 (D)	0.34 (D)	0.38 – 0.407(D)
- Buses					15 (D)	50 g/system (D)	0.15 (D)	0.34 (D)	0.38 (D)
- Ships					25 (CS)	0.01 (CS)	0.1 - 0.3 (CS)	NO	NO
- Railway vehicles					25 (CS)	0.005 (D)	0.06 (CS)	NO	NO
- Agricultural machines					10 (CS)	5 g/system (CS)	0.15 - 0.25 (CS)	0.34 (CS)	0.117 (CS)
Stationary air conditioning systems	2.F.1f								
- Large air conditioning systems		Tier 2a	HFC		15 - 25 (D)	0.005 (D)	0.036 - 0.06 (D)	0.9 (D)	0.658 - 0.765 (D)
- Heat pumps					15 (D)	0.005 (D)	0.02 - 0.025 (D)	0.75 (D)	0.5 - 0.545 (D)
- Heat-pump dryers					15 (CS)	0.005 (2008 - 2012) (CS)	0.003 (CS)	NO	NO
- Mobile room air conditioners					10 (D)	NO	0.025 - 0.034 (D)	0.75 (D)	0.242 - 0.295 (D)
- Single-split units					10 (D)	5 g/system (CS)	0.05 - 0.069 (D)	0.875 (CS)	0.379 - 0.46 (D)
- Multi-split units					13 (D)	20 g/system (D)	0.055 - 0.079 (D)	0.875 (CS)	0.62 - 0.66 (D)
- VRF devices					13 (D)	45 g/system (D)	0.064 - 0.081 (D)	NO	NO

Equ. = Equation from the IPCC GPG (2000)

Table 153: Overview of methods and emission factors used, for the current report year, in categories 2.F.2 (Foam blowing), 2.F.3 (Fire extinguishers), 2.F.4 (Aerosols), 2.F.5 (Solvents) and 2.F.6 (Other)

	QG	Method	Gas		Lifetime	Emission factor (dimensionless)		
			HFC	PFC	[years]	Production	Application	Waste management
2. Foam blowing	**2.F.2**							
closed-cell	2.F.2a							
- PUR hard foam with 134a					50 (D)	0.1 (D)	0.005 (D)	NO
- PUR hard foam with 227ea/245fa/365mfc		Tier 2a	HFC		50 (D)	0.15 (D)	0.01 (D)	NO
- XPS foam with 134a/1234ze					50 (D)	C	0.0066 (CS)	NO
open-cell	2.F.2b							
- XPS foam with 152a		Tier 2a			-	1 (CS)	NO	NO
- PUR integral foam with 134a, 227ea, 245fa, 365mfc		Tier 2a			-	1 (CS)	NO	NO
- PU one-component foam (134a)			HFC		-	0.5 g/can (CS)	1 (CS)	NO
- PU one-component foam (152a)		Tier 2a			-	0.5 g/can (CS)	1 (CS)	NO
3. Fire extinguishers	**2.F.3**	CS	HFC			0.001 (CS)	0.01 – 0.08 (CS) 0.04 (D)	1.0 (D)
4. Aerosols	**2.F.4**							
Metered dose inhalers	2.F.4a	Tier 2a	HFC		-	0.01 (CS)	1 (CS)	NO
Other aerosols / novelties	2.F.4b/c	Tier 2a			-	0.015 (CS)	1 (CS)	NO
5. Solvents	**2.F.5**	Tier 2	HFC		-	NO	1 (D)	NO
6. Other applications that use ODS substitutes	**2.F.6**					NO	NO	NO

Halocarbons are used in a number of different applications. Whereas in some, so-called "open" applications, consumed quantities are emitted completely, in the same year in question, in other applications large quantities are stored (stocks). The substances then are emitted, either partially or completely, from such "stocks" throughout the entire usage phase and in relevant waste management. Most of the EF used are either country-specific (CS) or IPCC default (D).

The emissions as listed in the inventory tables consist of the quantities of HFCs and PFCs that, during a report year, slowly escape from "stocks" and are emitted in production and waste management.

In general, the emissions data collected for the various product groups comprise emissions from production, use and waste disposal. Except where indicated otherwise in connection with the pertinent methods, these emissions are calculated as follows:

1. Production emissions are determined via new domestic consumption, as activity data:

   Equation 1:

   $EM_{production}$ = New domestic consumption * $EF_{production}$

2. Application emissions are based on the final stocks of relevant pollutants (the activity data), and they are calculated via the following formula:

   Equation 2:

   EM_{use} = Final stocks * EF_{use}

   The final stocks for the current year are calculated by summing annual new additions, from the first reporting year to the current one. The new additions for a given year consist of the new domestic consumption for that year, minus production emissions and losses from removals. The calculation thus requires consideration of foreign trade.

3. Disposal emissions refer to new additions for the year that is x years (depends on product lifetime) prior to the current reporting year n:

Equation 3:

$EM_{disposal}$ = New additions (n-x) * $EF_{disposal}$

15. For refrigeration and air-conditioning systems, the disposal emissions are calculated with equation 7.14 of the 2006 IPCC Guidelines:

Equation 4:

$EM_{disposal}$ = new additions (n-x) * residual charge level * (1 - recovery factor)

In this chapter, the sections *Uncertainties and time-series consistency, Category-specific quality assurance / control and verification, Category-specific recalculations and Planned improvements* vary in their reference – some refer to the entire relevant category, some to the sub - category in question and some to only a part of a sub - category. In each case, the reference involved is apparent from the CRF number in the section heading.

4.7.1 Refrigeration and air conditioning systems (2.F.1)

4.7.1.1 Category description (2.F.1)

This category is divided into the sub-categories of commercial refrigeration, household refrigeration, industrial refrigeration, transport refrigeration, mobile air conditioning systems and stationary air conditioning systems (cf. Table 152).

In Germany, the leading HFC refrigerants, far and away, are HFC-134a and the mixtures R404A, R407C, R410A, R422D and R507A.

For calculation of HFC emissions from the sub-categories of refrigeration and stationary air conditioning systems, individual data are collected, or refrigerant models are used. Any refrigerant models used are described in connection with the relevant method.

The emission factors used were obtained via surveys of experts. Disposal emissions in this category first occurred in 2000, in sub- categories 2.F.1.a (commercial refrigeration) and 2.F.1.e (mobile air-conditioning systems).

4.7.1.2 Methodological issues (2.F.1)

4.7.1.2.1 Commercial refrigeration (2.F.1.a)

Commercial refrigeration is the largest and most diverse area of (H)FC application. It is subdivided into the areas of plug-in devices, condensing units and central systems. The great diversity seen in the area of central systems, with regard to model, size, type of refrigerant and emissions-tightness, results from the fact that most relevant systems are customised systems. Less diversity is found in the areas of plug-in devices and condensing units.

Use of (H)FCs as refrigerants grew only gradually. For example, HFC-134a was not used on any significant scale until mid-1993. Use of the refrigerant mixture R404A also did not begin until 1993. The refrigerant mixture R407C has been used since 1996, and the various R422 mixtures, which are used as "drop-in" refrigerants in conversions of HCFC-22 systems, have been used only since 2009. In addition, since 1993 small quantities of PFC-containing refrigerant mixtures, such as R403A/B, R413A, Isceon 89 and R508A/B, have also been used, as drop-in refrigerants.

Today, the mixture R404A is the most important HFC refrigerant for stationary refrigeration systems, ranking ahead of even HFC-134a in this category. The mixtures R407C and R422D are now also of some significance.

In light of the extremely large number of companies specialising in refrigeration, detailed statistical surveys of refrigerant stocks are not practicable. Therefore, a different calculation method is used.

For calculation of emissions from *central systems* for commercial refrigeration, in the food retail sector, the following refrigeration model is used (cf. SCHWARZ et al., n.y.):

- Foreign trade with locally installed refrigeration systems plays a negligible role, and thus annual HFC consumption for new systems is the same as new HFC additions in new systems.
- The starting point for the calculations is not the number of plants involved or the installed cooling capacity, but the sales floor area of the relevant food retail stores, since that figure is statistically recorded, on an annual basis. Discount stores in Germany have sales floor areas of about 800 m^2, and that figure is a relatively constant one. All such stores are assumed to have basically the same refrigeration requirements and, thus, to use the same quantities of refrigerants. This is why in this case the number of discount stores involved serves as the basis for further calculations. The numbers of discount stores are also statistically recorded on an annual basis.
- On the basis of a study of the EPEE (SKM Enviros, 2010), the coefficient "kilograms per square meter of sales floor area" is derived for a typical, average-size supermarket. It has the value 0.23 kg/m^2. For discount stores, the coefficient "kilograms per discount store" is determined. It has the value 80 kg / store. Those coefficients are used to calculate the annual refrigerant stocks for the six store formats self-service department store (SB-Warenhaus), large retail store, small retail store, supermarket, cash & carry and discount store.
- The refrigerant stocks for the various store formats, subdivided by refrigerant types, are determined with the help of applicable component percentages for refrigerant combinations. The refrigerant combinations are derived with the help of statistical calculation models based on experts' assessments. In the process, a basic distinction is made between large stores (cash and carry stores, large retail stores and self-service department stores and small stores (supermarkets, small retail store and discount stores).
- Division of refrigerant stocks by the systems' average lifetime (14 years) yields the HFC additions via new systems.
- The production emissions and emissions from stocks are calculated with Equation 1 and Equation 2. Production normally takes place at the relevant sites.
- Replacement of CFCs and HCFCs in old systems is considered separately.

- Disposal emissions occurred in connection with central systems for the first time in 2000. Removals of refrigerants are calculated with the help of the average lifetime, which is 14 years for central systems. In each case, the nominal quantity for disposal is equivalent to the added new quantity a system had when it was commissioned. In practice, however, the quantities of refrigerants that systems contain when they are disposed of are smaller than the corresponding nominal charges, since systems are normally not recharged before they are decommissioned. For this reason, the actual charge level upon disposal, the "effective" quantity for disposal, is determined with the help of applicable percentage values for residual charges. The most important factor that enters into the determination of residual charges is the refrigerant-loss level at which a system has to be recharged in order to maintain its proper function. The effective charge level at the end of a device's / system's service lifetime is larger, by half of the difference between that minimum "technical" charge level and the nominal charge level, than the minimum "technical" charge level. For central systems, it amounts to 87.5 % of the nominal charge level.
- The disposal emissions are calculated by multiplying the so-determined "effective" quantity for disposal by the inverse of the recovery factor, using Equation 4:

Also in the case of *condensing units* for commercial refrigeration, the refrigerant stocks are the central point of reference for the refrigerant model for emissions calculation:

- The starting point for such calculations consists of the number of operation sites in the numerous sectors in which condensing units are used; the relevant sector selection is based on a study of the German Engineering Federation (VDMA) (2011). Such sectors include cash-and-carry beverage stores, service station shops, nurseries (garden centers), flower shops, flower wholesalers, cafeterias, caterers, hospitals, nursing homes, restaurants and hotels, butcher shops and franchise outlets for meat products, bakeries and franchise bakery outlets, discount stores, small food retailers and specialty food retailers. The number of sites involved is updated annually, from publicly accessible statistics.
- The refrigerant stocks for the various individual sectors are calculated as the product of the relevant number of operational sites, the sector-specific charges (as determined from the literature and via surveys of experts) and the refrigerant combinations involved (with percentage shares for the pertinent components). The refrigerant combinations are derived via a static calculation model (cf. SCHWARZ et al., n.y.).
- Division of total refrigerant stocks by the average lifetime of condensing units (12 years) yields the HFC additions via new systems.
- The production emissions and emissions from stocks are calculated with Equation 1 and Equation 2.
- The disposal emissions are calculated via Equation 4. The nominal quantity for disposal is identical, in terms of both quantity (amount) and refrigerant combinations, with the corresponding initial-charge quantity from 12 years earlier. For condensing units, the effective charge level at the end of units' service lifetime amounts to 85 % of the nominal charge level.

The application sectors for hermetically sealed *plug-in appliances* are largely the same as those for condensing units. Emissions for such appliances are calculated in keeping with the refrigerant-model approach described for condensing units. Such appliances have an average lifetime of 10 years, and their residual charge level upon disposal amounts to 90 % of the nominal charge level.

Emission factors

The emission factors used are the result of surveys of experts and literature evaluations.

As a rule, charging of refrigeration systems produces only small quantities of emissions. For "initial emission" in Table 7.9, the 2006 IPCC Guidelines give values of 0.5 to 3 percent of the initial charge for plug-in devices and for medium-sized and large commercial refrigeration systems. The country-specific $EF_{production}$, at 0.5 % for plug-in devices and at 1 % for central systems and condensing units, lie within this range.

Ongoing (H)FC emissions from stationary refrigeration systems in the *commercial refrigeration* category vary widely in keeping with the type of system concerned. The refrigerant loss ranges from 1 to 1.4 %, for plug-in individual units, to 6.4 to 9.7 %, for condensing units and to 10.5 to 19.5 % for central systems. The emission factors for application have decreased continuously since 1993 for all devices and systems in the area of commercial refrigeration (cf. Table 152), in keeping with the increasing degree of care taken in handling refrigerants. Measured against the value ranges given in Table 7.9 of the 2006 IPCC Guidelines, 1 for 15 % for individual units and 10 to 35 % for medium-sized and large commercial refrigeration systems, the emission factors either lie within low range sections (individual units and central systems) or lie below the ranges (condensing units).

The average lifetimes prior to disposal are 10 years (individual units), 12 years (condensing units) and 14 (central systems). The lifetimes used thus lie within the relevant ranges given in the 2006 IPCC Guidelines, 10 to 15 years (individual units) and 7 to 15 years (medium-sized and large commercial refrigeration systems).

The residual charges in the devices and systems, at the end of their lifetimes, and with respect to the initial charge in each case, are 90 % (individual units), 85 % (condensing units) and 87.5 % (central systems). The 2006 IPCC Guidelines give value ranges of 0 – 80 % (individual units) and 50 – 100 % (medium-sized and large commercial refrigeration systems). All of the values used are thus default values.

The recovery factors have been increasing continuously, and thus the losses occurring upon disposal, with respect to initial charge / residual charge, have been decreasing over the years concerned. For plug-in devices, the recovery factor was 32.6 % in 2003 and 46 % in 2013. For condensing units, the recovery factor was 47.5 % in 2005 and 66 % in 2013, while for central systems the recovery factor increased from 42.9 % in 2000 to 76.0 % in 2013. As a result, most of the recovery factors used lie within the value range given in Table 7.9 of the 2006 IPCC Guidelines, 0 to 70 %. The only recovery factor values used that are higher than the IPCC values are those used for central systems, for the period as of 2009.

Activity data

The sales floor areas of grocery stores are surveyed annually, by two market-research institutes[64]. The EHI Retail Institute also monitors the numbers of discount stores. In addition, the applicable numbers of commercial sites are updated annually from various publicly available statistics (cf. SCHWARZ et al., n.y.).

[64] EHI – EHI Retail Institute, Cologne; The Nielsen Company GmbH, Frankfurt am Main.

The quantities and types of refrigeration and freezer systems typically used by businesses are determined from the literature and via estimation by experts. The coefficients "kilograms per square meter of sales floor area" and "kilograms per discount store" have been determined semiempirically by experts, with the help of the relevant technical literature (SKM ENVIROS, 2010, CLODIC et al., 2011 und 2012). The charges for condensing units and plug-in appliances have been determined via techical discussions with German manufacturers of refrigeration / freezer systems and via study of the relevant literature.

4.7.1.2.2 Household refrigeration (2.F.1.b)

In 1994, domestic producers of household refrigerators and freezers made a changeover from CFC-12 to HFC-134a. In Germany, they then switched to isobutane a short time later. Small numbers of devices containing HFC-134a, representing a small share of all relevant appliances, have been imported since 1993.

Production losses and new consumption for domestic purposes do not have to be determined, since all filling with HFC takes place abroad.

Equation 2 is used to calculate annual HFC emissions on the basis of final stocks. This is done by determining and aggregating the annual HFC new additions since 1993 and then subtracting the aggregated annual removals via disposal.

Disposal emissions occurring as of the year 2008, following an average lifetime of 15 years, are calculated with Equation 4.

Emission factors

Current HFC emissions from household refrigerators and freezers are estimated at 0.3 %, which is within the value range given by the 2006 IPCC Guidelines in Table 7.9, 0.1 to 0.5 %

The average lifetime prior to disposal is 15 years. The system lifetimes used thus lie within the range given by the 2006 IPCC Guidelines, 12 to 20 years.

The residual charges in devices, with respect to initial charge, average 95.5 %. The relevant values given in the 2006 IPCC Guidelines range from 0 to 80 %. The value used is thus higher than the range given in the 2006 IPCC Guidelines. The value is justified in light of the low refrigerant losses that occur during the use phase (0.3 % per year; 4.5 % throughout the entire use phase); those losses do not substantiate use of lower values for the residual charge level.

The recovery factor is 73.3 %, which is slightly above the range given in Table 7.9 of the 2006 IPCC Guidelines, 0 to 70 %. The higher recovery factor has been brought about by legislation (the Electrical and Electronic Equipment Act – Elektrogesetz) governing the disposal of household appliances.

Activity data

The annual additions figure of 1 % of new appliances is an estimate of leading refrigerator manufacturers.

4.7.1.2.3 Industrial refrigeration (2.F.1.c)

The industrial refrigeration included in this sector refers to refrigeration for production of products – mostly food and drink – that are refrigerated or frozen.

Refrigeration systems in this category, as in the category of *commercial refrigeration*, are usually not purchased directly from series production. They tend to be customised systems, and thus emissions for this category have to be calculated with the help of a refrigeration model. Use of fluorine-based refrigerants has not yet become standard practice in industry, especially the food industry. In addition, natural refrigerants – primarily ammonia – are used much more frequently in this sector than they are in other sectors.

The leading refrigerants for industrial refrigeration are R404A, HFC-134a, R407C, R507A and R422D. The last of these serves as a substitute refrigerant for converted HCFC-22 systems. HFC-23 und PFC-116 are also used, in low-temperature systems, while the refrigerant HFC-227ea is used in air-conditioning systems for cranes and in high-temperature heat pumps.

Use of fluorine-based refrigerants began in Germany in 1993. Disposal emissions began occurring in 2002, from converted CFC-12 and HCFC-22 systems.

The following refrigerant model is used for *industrial refrigeration*:

- The refrigerant stocks serve as the central point of reference for the model. The model is divided into the following twelve major industrial refrigeration sectors: beer breweries, wine production, meat production, dairies, cold-storage facilities, chocolate production, production of frozen foods and of juices, skating rinks, milk refrigeration in the agricultural sector, other industry (80 % chemical industry) and hermetically sealed appliances in manufacturing. The basis for calculation of the refrigerant stocks consists of the quantities of produced goods. They are updated annually via publicly accessible merchandise statistics.
- In the three smaller sectors of industrial refrigeration, air-conditioning for cranes, high-temperature heat pumps and low-temperature refrigeration with HFC-23 (primarily in the plastics industry) and R508A/B, the annual new additions are used as the starting value for calculating stocks and all emissions.
- On the basis of the relevant production quantities, a conversion is made to the installed cooling capacity required for cooling goods and products in the twelve major sectors. The key factors required for that conversion, "installed cooling capacity per units of annual goods production", have been determined empirically, on the basis of the technical literature.
- The refrigerant quantities required for the resulting cooling capacity are estimated on the basis of refrigerant-use rates for plus and minus refrigeration and for direct and indirect refrigeration. The refrigerant-use rates were also determined via study of the literature, including CLODIC et al. 2011 & 2012. They range from 2 kg/kW for indirect plus refrigeration to 8.8 kg/kW for direct minus refrigeration. The typical charges per installed unit of cooling capacity are calculated, for the twelve sectors, by combining these values with the applicable sector-specific weightings for the four basic forms of refrigeration.
- Foreign trade with locally installed refrigeration systems plays a negligible role, and thus annual HFC consumption for new systems is the same as new HFC additions in new systems.

- The refrigerant stocks also provide the basis for calculating the quantity for disposal. For each sector, that quantity is calculated by dividing the stocks by devices' service lifetimes. For most sectors, the applicable service lifetime is 30 years. For dairy farms and skating rinks, it is 20 years, and for plug-in appliances, air conditioners for cranes, high-temperature heat pumps and low-temperature applications, it is 10 years.
- The refrigerant combinations, which vary over time for stocks, new additions and quantities for disposal, are derived for each sector via a static calculation model (cf. SCHWARZ et al., n.y.).
- Replacement of CFCs and HCFCs in old systems is considered separately.
- The production emissions and emissions from stocks are calculated with Equation 1 and Equation 2.
- The disposal emissions are calculated with Equation 4. The nominal quantity for disposal is identical with the initial-fill quantity. The effective charge level at the end of devices' service lifetimes is 85 % of the nominal charge level, for all sectors except plug-in appliances, for which it is higher – 90 %.

Emission factors

The emission factors on which the emissions data are based are listed in Table 152.

The emission factors used are the result of surveys of experts and literature evaluations.

As a rule, charging of industrial refrigeration systems produces only small quantities of emissions. In Table 7.9, the 2006 IPCC Guidelines give for "initial emission" values of 0.5 to 3 percent of the initial charge quantity. The country-specific $EF_{production}$ for the sectoral application areas is 1 %, while it is 0.5 % for plug-in appliances. The EF thus lie within the lower part of the range given by the Guidelines.

In all sectors except hermetically sealed appliances, ongoing HFC emissions from industrial refrigeration systems have been decreasing continually, changing from 8.8 % in 1993 to 5.9 % in 2013. The reason for this trend is that refrigeration systems' capacity for retaining their refrigerants has improved as a consequence of national and international legislation. Such emissions now lie within the lower part of the range, or even slightly below the range, given by the 2006 IPCC Guidelines in Table 7.9 – 7 % to 25 %. For plug-in appliances, the decrease has been comparable to that seen in commercial refrigeration: from 1.4 % in 1994 to 1 % in 2013.

The average applicable lifetimes prior to disposal are as follows: 10 years (plug-in individual units, air-conditioners for cranes, high-temperature heat pumps, low-temperature applications and plastics industry); 20 years (dairy operations, skating rinks); and 30 years (food industry, cold-storage systems, chemical industry). The lifetimes used – with the exception of the 10-year lifetimes for certain application areas – thus lie within the value range given by the 2006 IPCC Guidelines, 15 to 30 years.

The residual charges in the devices and systems, at the end of their lifetimes, and with respect to the initial charge level in each case, are 90 % (individual units) and 85 % (sectoral application areas). The relevant values given in the 2006 IPCC Guidelines for industrial refrigeration systems range from 50 to 100 %. All of the values used are thus default values.

The recovery factors have been increasing continuously, and thus the losses occurring upon disposal, with respect to initial charge / residual charge, have been decreasing over the years concerned. For plug-in individual units, the recovery factor was 33.7 % in 2004 and 46 % in 2013. For refrigeration systems of sectoral application areas, the recovery factor was 45 % in 2002 and 76.5 % in 2013. The recovery factors used thus lie within the range given in Table 7.9 of the 2006 IPCC Guidelines, 0 to 90 %.

Activity data

The statistics of the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) contain numerous time series for food-production quantities. In addition, data are available from industrial associations such as the German association of cold-storage facilities and cold-chain logistics companies (VDKL) and the Association of the German Confectionary Industry (BDSI), as well as from specialised institutes, such as the German Wine Institute.

The unit-number figures for plug-in appliances have been taken from a study of the German Engineering Federation (VDMA) (2011) and provided by industry experts.

The "installed cooling capacity per units of annual goods production" indices, and the refrigerant-use rates for plus and minus cooling and for direct and indirect cooling, were determined on the basis of information provided in the relevant technical literature.

4.7.1.2.4 Transport refrigeration (refrigerated vehicles and containers) (2.F.1.d)

HFCs have been used as refrigerants in *refrigerated vehicles* since 1993. Today, HFC-134a, along with the refrigerant mixtures R404A and R410A, are most commonly used. The sizes and refrigerant charges of refrigeration systems vary in keeping with the load volumes of the refrigerated vehicles in question.

Refrigerated containers are used primarily for transports of perishable goods by ocean-going ships. Since their emissions take place primarily in international waters, their refrigerant emissions are divided, in each case, in keeping with the relevant country's share of world trade. Germany is assigned 10% of global emissions from refrigerated containers. Since 1993, the most commonly used refrigerant has been HFC-134a. Since 1997, R404A has also been used.

The following refrigeration model is applied to *refrigerated vehicles*:

- Refrigerated vehicles are divided into four weight-based size classes: 2-5 t, 5-9 t, 9-22 t and > 22 t of gross vehicle weight.
- Refrigerant types, and specific refrigerant charge amounts, are assigned to the various size classes. Each refrigerant is also assigned a percentage share of each size class. Since report year 2006, half of the small systems of up to 5 t gross vehicle weight have been charged with the refrigerant R404A and half have been charged with HFC-134a. From 1993 through 2005, only HFC-134a was used. Since 1993, 50 % of refrigerant charges in the size class 5-9 t gross vehicle weight have consisted of HFC-134a and 50% have consisted of R404A , while HFC-134a, R404A and R410A have been used in the size classes 9-22 t and > 22 t. In these size classes, R404A predominates, with a share of 80 and 85 %, respectively.
- The number of newly licensed refrigerated vehicles, and the number of refrigerated vehicles charged within the country (broken down by refrigerants), are determined for each year.
- The production emissions are calculated using Equation 1 , on the basis of the new consumption required for charging domestically produced refrigerated vehicles.

- The annual new additions of refrigerants result from the numbers of newly licensed refrigerated vehicles and the above assumptions.
- From 1996 to 1999, HFCs were substituted for CFC-12 in a certain number of old systems. These amounts have to be included in the annual new additions.
- The year-end final stocks are obtained by aggregating the annual HFC new additions since 1993 and then subtracting the removals via disposal.
- Equation 2 is used to calculate annual HFC emissions on the basis of final stocks.
- Disposal emissions occurred in connection with refrigerated vehicles for the first time in 2003. They are calculated by means of Equation 4. The nominal quantity for disposal is identical to the new additions 10 years earlier (or 7 years earlier in the case of converted CFC-12 systems). The effective charge level at the end of units' service lifetimes amounts to 87.5 % of the nominal charge level.

For *refrigerated containers*, the following refrigerant model is used:

- The number of refrigerated containers produced worldwide is determined for each year.
- The worldwide HFC additions for refrigerated containers are determined on the basis of annual unit figures from global production, in combination with the relevant charges and charge percentages for the various relevant refrigerants.
- Germany's HFC additions are determined from worldwide additions, in keeping with Germany's share of global trade, which amounts to 10 %.
- Since refrigerated containers are produced only outside of Germany, no emissions from charging occur in Germany.
- The year-end final stocks are obtained by aggregating the annual HFC new additions since 1993 and then subtracting the removals via disposal.
- Emissions from stocks are calculated with Equation 2.
- Refrigerated containers have an average lifetime of 14 years, and disposal emissions from such containers occurred for the first time in 2007. They are calculated by means of Equation 4.

Emission factors

The emission factors on which the emissions data are based are listed in Table 152.

The emission factors used are the result of surveys of experts and literature evaluations.

As a rule, charging of refrigerated vehicles produces only small quantities of emissions. The losses of refrigerant during charging are estimated at 5 grams per system, regardless of system size. That is a standard value for hose losses during on-site charging. When emissions from charging are calculatorily considered in relation to new consumption, emission factors between 0.06 und 0.25 % result. For "initial emission" in transport refrigeration, the 2006 IPCC Guidelines give figures, in Table 7.9, of 0.2 to 1 percent of the initial charge. As a result, the great majority of the values used lie below the range recommended in the IPCC Guidelines.

Since no domestic production of refrigerated containers takes place, no emissions from charging of such containers occur.

Ongoing HFC emissions from new refrigeration units of refrigerated vehicles in the range 5-22 t gross vehicle weight are estimated to amount to 15 %. For units in vehicles up to 5 t gross vehicle weight, the emission factor is 30 %. For old units in refrigerated vehicles (converted CFC-12 systems), the emission factor for emissions from stocks is estimated to average 25 %, for all unit size classes. The emission factors for refrigerated vehicles thus lie at the lower end of the range given in Table 7.9 of the 2006 IPCC Guidelines, 15 to 50 %.

For refrigeration units, the figure for emissions from stocks is 10 %, which is slightly below the range given in Table 7.9 of the 2006 IPCC Guidelines, 15 to 50 %.

The lifetime of old systems in refrigerated vehicles is 7 years, while that of new systems in refrigerated vehicles is 10 years. The average lifetime for refrigerated containers prior to disposal is 14 years. The lifetimes used – with the exception of those for old systems in refrigerated vehicles – thus lie within the value range given by the 2006 IPCC Guidelines, 6 to 9 years.

The residual charges in refrigerated vehicles and refrigerated containers, with respect to initial charge, average 87.5 %. The relevant values given in the 2006 IPCC Guidelines for transport refrigeration systems range from 0 to 50 %. All of the values used are larger than those given in the Guidelines, since it must be assumed that transport refrigeration systems that only have 50 % of their initial charges left no longer function properly and thus would compromise the cold chain, with the result that the chain would no longer be seamless. The act of allowing that to happen would violate German law.

The recovery factor for refrigerated vehicles and refrigerated containers is 65.7 %. The recovery factors used thus lie within the range given in Table 7.9 of the 2006 IPCC Guidelines, 0 to 70 %, and thus are default values.

Activity data

Until 2008, and as of 2011, the registration figures for refrigerated vehicles, broken down by weight classes, were taken from statistical reports of the Federal Motor Transport Authority (KBA). Since in 2009 and 2010 the Federal Motor Transport Authority stopped carrying out separate surveys of refrigerated vehicles, the numbers of new refrigerated vehicles for those two years are determined via extrapolation from the registration figures for utility vehicles as determined by the KBA. Charges in refrigeration systems, information on refrigerants used, and details on CFC-12 replacement were provided by experts of the leading providers of refrigeration units for refrigerated vehicles.

New additions of refrigerants in the area of refrigerated containers are determined via a refrigerant model based on the numbers of refrigerated containers produced worldwide, with the numbers provided by the "World Cargo News" information service for the industry. A 10 % share is allocated to Germany.

4.7.1.2.5 Mobile air-conditioning systems (2.F.1.e)

The mobile air-conditioning systems category includes air-conditioning systems in automobiles, trucks and utility vehicles, buses, agricultural machinery (tractors, combines, field choppers) and railway vehicles, and on ships. Hydrofluorocarbons (HFCs) have been used in mobile air-conditioning systems since 1991. HFC-134a is a commonly used HFC refrigerant. Since 2012, HFC-1234yf has also been used in automobile air-conditioning systems.

The time series show a significant emissions increase since 1995. This increase, which has occurred in spite of decreases in charge quantities, is a direct result of increased use of mobile air conditioning systems in vehicles.

For *automobiles*, the following refrigeration model is applied:

- The production figures for German automobile production are available, on an annual basis, from the publicly accessible statistics of the German Association of the Automotive Industry (VDA). Those figures provide the database for calculating consumption data relative to charging.
- The annual percentages of automobiles equipped with air-conditioning systems are obtained via extensive surveys of manufacturers, since they are not provided by any official or publicly available statistics. This also applies to the average refrigerant (charge) quantities, which are determined from the technical data for the various automobile models and from information provided by industry experts.
- The quantities consumed in charging such air conditioners are calculated by multiplying the numbers of automobiles produced by the annual percentages of automobiles equipped with air-conditioning systems and by the average per-unit refrigerant (charge) quantities.
- Production emissions are computed with Equation 1.
- The annual numbers of new vehicle registrations as recorded by the Federal Motor Transport Authority (KBA) are not used in determining annual new additions and the refrigerant stocks in automobile air conditioning systems, since it is not possible to quantitatively estimate early departures of vehicles (i.e. prior to vehicles' reaching the end of their average lifetimes) from the registration cohorts that form the basic fleet.
- Instead, the refrigerant stocks are determined on the basis of the numbers of registered vehicles on the road, divided according to age since the initial registration. Relevant official data are available from the statistical communications (Statistische Mitteilung) of the KBA[65], for all required years, i.e. as of 1991. They make it possible to determine, on a continuous, chronological basis, the numbers of vehicles in the total fleet, divided by registration cohorts.
- The annual percentages of automobiles equipped with air conditioning systems, for newly registered vehicles, are also obtained via extensive surveys of manufacturers. Those numbers are not identical with the corresponding percentages of automobiles produced in Germany and equipped with air conditioning systems, since foreign cars also have to be taken into account. The necessary percentages are thus also obtained via surveys of foreign companies. This also applies to strategies for determining the average per-unit refrigerant (fill) quantities in newly registered vehicles.
- The refrigerant stocks in each registration cohort are calculated by multiplying the specific charges for the year in question by the numbers of automobiles equipped with air conditioners. The total stocks are equivalent to the sum of the refrigerant stocks for all registration cohorts since 1991.
- Emissions from stocks are calculated with Equation 2.
- Replacement of CFCs in old systems, and air-conditioner retrofits, are considered separately.

[65] KBA "Fahrzeugzulassungen Bestand an Kraftfahrzeugen und Kraftfahrzeuganhängern nach Fahrzeugalter 1. Januar 2013".

- In determination of quantities for disposal, only the old vehicles are taken into account that are handled each year by German dismantling facilities. Those numbers are obtained from the official data on old vehicles[66] (cf. also UBA/BMUB, 2014). The refrigerant model does not take account of exports of used cars and old cars, since the relevant disposal emissions occur in the pertinent destination countries and double-counting has to be avoided.
- An average lifetime of 15 years is assumed for dismantled vehicles. The total quantity of refrigerants that are disposed of can be determined by multiplying the number of dismantled vehicles by the applicable percentage of vehicles equipped with air conditioning systems and the average per-unit refrigerant (charge) quantity for the relevant new-registration cohort of 15 years earlier.
- Disposal emissions occurred for the first time in 2002. They are calculated with Equation 4.
- HFC-1234yf is reported under "Additional Greenhouse Gases". In keeping with the recommendation in Paragraph 33 of the 2014 UNFCCC Reporting Guidelines, in addition to reporting on greenhouse gases as required, Germany is reporting on a number of emissions not subject to reporting obligations. For reasons of confidentiality, those emissions data have been combined with data on other emissions not subject to reporting obligations. They are reported in Chapter (CRF 2.H).

The refrigerant models for *utility vehicles and buses* are structured similarly to the model for automobiles. A detailed description of those models is provided by SCHWARZ et al. (n.y.).

The refrigerant model used for *agricultural machinery*, *ships and railway vehicles* is as follows:

- For ships and railway vehicles, refrigerant emissions are determined on the basis of annual new installations of air conditioning systems in ships (outset data: newly built ships for the German fleet) and in railway vehicles (outset data: new procurements by German Railways (DB) and private companies), as well as the relevant charges.
- The refrigerant model for air conditioning systems in agricultural machinery is based on the number of new vehicle registrations for each year, the average percentage of vehicles equipped with air conditioning systems and the average charges.
- The annual new additions of HFC-134a, as well as the final stocks, are determined, for each area, from the relevant previous set of data.
- Emissions from stocks are obtained, using Equation 2, by multiplying the final stocks, for each area, by the relevant EF_{use}.
- Domestic consumption of HFC-134a, for production of mobile air conditioning systems, is determined on the basis of unit-number figures for production. Production emissions are computed with Equation 1 errechnet..
- Disposal emissions in the agricultural machinery category occurred for the first time in 2004, at the end of the average lifetime for the category, 10 years. They are calculated by means of Equation 4. Due to the long lifetimes involved – 25 years – no air conditioning systems in ships and railway vehicles have been disposed of yet.

Emission factors

The emission factors on which the emissions data are based are listed in Table 152.

[66] Statistisches Bundesamt (Federal Statistical Office), Fachserie 19 / Reihe 1, Umwelt Abfallentsorgung ("environment – waste management").

The emission factors used have been obtained via evaluation of the relevant literature (e.g. ÖKO-RECHERCHE / ECOFYS 2003; SIEGL et. al., 2002; CLODIC et. al., 2011 und 2012; Öko-Recherche 2012, SCHWARZ et al., n.y.), measurements (automobiles), evaluations of service-center records, extensive surveys of experts and surveys of automobile service centers and dismantling facilities. In addition to regular emissions during operation, emissions also arise as a result of accidents and other external influences.

As a rule, charging of mobile air-conditioning systems produces only small quantities of emissions. For automobiles, the refrigerant losses upon charging are estimated as 3 grams per system. For utility vehicles and agricultural machinery, they are placed at 5 grams per system, and for buses they are considered to be 50 grams per system. These figures are standard values for hose leakage in connection with on-site charging. When the emissions from charging are seen, mathematically, in relation to new consumption, the following emission factors result: 0.25 - 0.63 % (automobiles), 0.42 - 0.66 % (utility vehicles), 0.28 - 0.35 % (agricultural machinery) and 0.42 - 0.45 % (buses). The ranges are the result of annual variations in initial charges. For railway vehicles, the emission factor for charging is 0.5 %, while for ships, it is 1 %. For "initial emission" for mobile air-conditioning systems (automobiles, utility vehicles,buses and railway vehicles), the 2006 IPCC Guidelines give figures, in Table 7.9, of 0.2 to 0.5 percent of the initial charge. The Guidelines provide no values for agricultural machinery and ships. The great majority of the values used for the vehicles described in the Guidelines thus lie within the relevant ranges proposed by the IPCC Guidelines.

Current HFC emissions are estimated at 10 % for automobiles; at 15 % for utility vehicles and buses; at 6 % for railway vehicles; for agricultural machinery, at 15 % (tractors) and 25 % (combines and field choppers); and, for ships, at 10 % (passenger ships on inland waterways), 20 % (ocean liners) and 30 % (ocean-going cargo ships). The EF_{use} used thus lie largely within the range proposed in Table 7.9 of the 2006 IPCC Guidelines, 10 to 20 % for air-conditioning systems in automobiles, utility vehicles, buses and railway vehicles. No proposals have been provided for agricultural machinery and ships.

The average lifetimes prior to disposal are 15 years (automobiles, utility vehicles, buses), 10 years (agricultural machinery) and 25 years (railway vehicles, ships). For railway vehicles, disposal will not begin until 2017, while for ships it will not begin until 2022. With the exception of those for systems in railway vehicles and on ships, the lifetimes lie within the value ranges given by the 2006 IPCC Guidelines for systems in automobiles, utility vehicles, buses and agricultural machinery, 9 to 16 years.

The residual charges remaining in air-conditioning systems, with respect to initial charge, average 34 % (automobiles, utility vehicles, buses, agricultural machinery). The relevant values given in the 2006 IPCC Guidelines range from 0 to 50 %. All of the values used are thus default values.

As a result of the disposal and recycling of end-of-life vehicles as required by the End-of-Life Vehicles Ordinance (Altfahrzeug-Verordnung) since 2002, the recovery factors for automobiles and utility vehicles have been increasing continuously, with the result that losses occurring upon disposal, with respect to initial charge or residual charge, have been decreasing over time. For automobiles and utility vehicles, the recovery factors amounted to 38 % in 2000, and to 40.67 % in 2013. For buses, the recovery factor is estimated at 38 %, and for agricultural machinery, at 11.7 %. The recovery factors used for automobiles, utility vehicles and buses thus lie within the range given in Table 7.9 of the 2006 IPCC Guidelines, 0 to 50 %. No recommendations have been provided for agricultural machinery.

Activity data

The Federal Motor Transport Authority (KBA) reports numbers of registered automobiles, utility vehicles and buses, and new registrations of agricultural tractors. The sources for production figures include the German Association of the Automotive Industry (VDA), the German Engineering Federation (VDMA), other statistics and surveys of manufacturers.

The charges in automobile air conditioners, and the annual percentages of automobiles equipped with air-conditioning systems, are determined via direct surveys of automobile companies. For systems in other types of vehicles, the charges and percentages are obtained by combining official statistics, information from surveys of manufacturers and experts' assessments.

4.7.1.2.6 Stationary air conditioning systems (2.F.1.f)

The area of stationary air conditioning systems includes room air conditioners, chillers for air conditioning of buildings and industrial refrigeration of liquids, heat-pump systems and heat-pump laundry dryers.

4.7.1.2.6.1 Room air conditioners

Room air conditioners are used to cool the interiors of individual rooms, entire floors or small-to-medium-sized buildings. Their performance levels tend to be lower than those of large air conditioning systems. The refrigerants used include the HFC mixture R407C (since 1998) and the mixture R410A (since 2001).

There is no domestic production of room air conditioners. Room air conditioners are normally already filled when imported. Installation of factory-manufactured single-split, multi-split and VRF-multi-split units involves installation of refrigerant lines, and these have to be charged on site, however. Such charging of lines is not required in connection with mobile, plug-in room air conditioners.

The following refrigeration model is used for room air conditioners:

- *Room air conditioners* are divided into four categories. The applicable numbers of new systems produced each year in each category are determined via surveys of manufacturers and via the data published in pertinent international publications. The categories are: small mobile units, single-split units, multi-split units with constant-volume refrigerant flow and VRF-multi-split systems with variable-volume refrigerant flow.
- For each category, the charges and refrigerant combinations are determined in keeping with the numbers of new systems sold each year. The annual new consumption, which is identical to annual new additions of refrigerants, is obtained from sales statistics and the above assumptions. The year-end final stocks are obtained by aggregating the annual HFC new additions since 1993 and then subtracting the removals via disposal.

- No production emissions occur. Charging losses do occur, however, in installation of stationary single-split units, multi-split units and VRF multi-split systems. Surveys of experts have indicated that the applicable losses during installation are 5 g per unit (10 % of the initial charge) for single-split units, 20 g per unit (1 % of the initial charge) for multi-split units and 45 g per system (1 % of the initial charge) for VRF multi-split systems.
- Emissions from stocks are calculated with Equation 2.
- Disposal emissions occurred for the first time in 2008. The average lifetime of mobile units and single-split units is 10 years, while the average lifetime of multi-split units and VRF multi-split systems is 13 years. Disposal emissions are calculated with Equation 4.

Emission factors

The emission factors used have been obtained via surveys of experts and evaluations of the literature; they are listed in Table 152.

The country-specific $EF_{production}$ = 1 % for multi-split units and VRF multi-split units lies within the value range given by the 2006 IPCC Guidelines, in Table 7.9 – 0.2 to 1 %. For single-split units, the emission factor is 10 %, which corresponds to a loss of 5 g of refrigerant per 50 g charge, and which is above the range given in the Guidelines.

For all devices, the emission factors for use decrease continually throughout the time series, beginning with the first year of use (cf. Table 152). For mobile room air conditioners, they range from 3.4 % (1999) to 2.5 % (2013); for single-split units, they range from 6.9 % (1998) to 5 % (2013); for multi-split units, they range from 7.9 % (1998) to 5.5 % (2013); and for VRF multi-split units, they range from 8.1 % (2003) to 6.4 % (2013).

The emission factors for use thus lie within the range given in Table 7.9 of the 2006 IPCC Guidelines, 1 to 10 %.

The estimated lifetimes for such units, 10 years (mobile room air-conditioners, single-split units) and 13 years (multi-split units, VRF multi-split units), lie within the value range given in Table 7.9 of the 2006 IPCC Guidelines, 10 to 20 years. The 13-year lifetime for VRF multi-split units means that disposal of such units will not begin until 2016.

The residual charge upon disposal is 75 % for mobile room air-conditioners and 87.5 % for all other types of units. The 2006 IPCC Guidelines, in Table 7.9, recommend values ranging from 0 to 80 %. The residual-charge figure used for mobile room air-conditioners is thus a default value, while the values used for single-split units and multi-split units are above the Guidelines' range.

The recovery factors have been increasing continuously, and thus the losses occurring upon disposal, with respect to initial charge / residual charge, have been decreasing over the years concerned. For mobile room air-conditioners, the recovery factor was 24.2 % in 2009 and 29.5 % in 2013; for single-split units, it was 37.9 % in 2008 and 46 % in 2013; while for multi-split units, it was 62 % in 2011 and 66 % in 2013. The recovery factors used thus lie within the range given in Table 7.9 of the 2006 IPCC Guidelines, 0 to 80 %.

Activity data

The numbers of units sold in Germany, of the various types of units and systems involved, are determined on an annual basis via technical publications[67] and surveys of sellers.

4.7.1.2.6.2 Chillers

The following refrigeration model is applied to *chillers*:

- Chillers are divided into three categories. The number of new systems in each of the following categories is determined each year via surveys of experts and international sales statistics: chillers ‹100 kW cooling capacity; chillers ›100 kW cooling capacity; and turbo-compressor systems in the performance range above 1500 kW.
- An average charge quantity and specific refrigerant composition are determined for each category. The charge quantities are 10 kg for chillers ‹100 kW, 95 kg for chillers ›100 kW and 630 kg for turbo-compressor systems.
- Data on annual HFC additions to domestic stocks are obtained from the numbers of new systems, in connection with the above assumptions. Consumption for CFC replacements in old systems has to be taken into account.
- The year-end refrigerant stocks can be calculated from the previous-year stocks, the new additions and the removals.
- Production emissions are calculated by multiplying the quantities consumed in charging by the $EF_{production}$, pursuant to Equation 1.
- Emissions from stocks are calculated with Equation 2.
- Disposal emissions occurred for the first time in 2003 (in conversion of systems for CFC substitutes). They are calculated with Equation 4.

IPCC-GPG (2000), Table 3.22, gives a service lifetime of 10 to 30 years for liquid chiller systems. The values used in the present case lie within that range: 15 years for chillers with cooling capacities either less or more than 100 kW, and 25 years for turbo-compressor systems.

Emission factors

The emission factors used are the result of surveys of experts. They are listed in Table 152.

The losses from charging, at 0.5 %, are within the range given in Table 7.9 of the 2006 IPCC Guidelines, 0.2 to 1 %. To take account of the fact that large numbers of chillers are imported as pre-charged units, $EF_{production\,=}$ 1 %, the actual $EF_{production}$, is not used.

The ongoing HFC emissions through 2000 are estimated at 6 % for all cooling-capacity classes / compressor models, age classes and refrigerant types. Thereafter, the EF_{use} decreases continuously, to 3.6 % (2013). All of the values used thus lie within the lower part of the range proposed by the 2006 IPCC Guidelines, 2 to 15 %.

The 2006 IPCC Guidelines, in Table 7.9, give a service lifetime of 15 to 30 years for liquid chiller systems. The values used in the present case lie within that range: 15 years for chillers with cooling capacities either less or more than 100 kW, and 25 years for turbo-compressor systems.

[67] The trade journal JARN – Japan Air Conditioning, Heating & Refrigeration News, Tokyo 107-0052, Special Edition "World Air Conditioner Market".

The residual charge upon disposal is 90 %, for all chiller types. The 2006 IPCC Guidelines, in Table 7.9, recommend values ranging from 80 to 100 %. The residual-charge figures used are thus default values.

The recovery factors have been increasing continuously, as a result of technical progress and greater care taken in handling refrigerants, and thus the losses occurring upon disposal, with respect to initial charge / residual charge, have been decreasing over the years concerned. The recovery factor for chillers, including units with cooling capacity less than 100 kW and greater than 100 kW, was 65.8 % in 2003 and 76.5 % in 2013, while the factor for turbo-compressor systems was 69.5 % in 2003 and 76.5 % in 2013. The recovery-factor figures used thus lie within the range given in Table 7.9 of the 2006 IPCC Guidelines, 0 to 95 %.

Activity data

The numbers of new systems are determined annually via surveys of experts and consultation of international sales statistics. The statistics are prepared by two market-research institutes[68].

The average charge quantities and refrigerant combinations are determined via consultations between experts and industry representatives.

4.7.1.2.6.3 Heat-pump systems

Via a refrigeration cycle, heat pumps draw heat from the air, ground or groundwater and make it available for heating or cooling indoor areas or for heating water. Devices that directly use heat from the outdoor environment to warm indoor air fall within the category of room air conditioners. Since 1995, HFC-134a and the HFC mixtures R404A and R407C have been used as refrigerants in heat pumps; since 2001, R410A has been used as well.

Methodologically, the refrigerant model for *heat pumps* is structured like the model for room air conditioners.

Three categories of heat pumps for heating are differentiated: air – water; ground (groundwater) – water; ground (brine) – water. Heat pumps for pumping hot process water are treated as a fourth category.

The starting and reference point for calculations consists of the annual numbers of newly installed heat-pump units in each of the four categories. These data are published annually by the German heat-pump association (BWP). The numbers of newly installed heat pumps for hot process water are also used as production quantities. The produced quantities of heat pumps for heating are larger, by a factor of 2, than the numbers of newly installed pumps. On the basis of the data for new additions, the various heat-pump types are assigned average HFC-charge quantities and percentage shares of the various types of HFCs. The model also includes service-life and emissions-rate figures.

Production emissions are calculated by multiplying the quantities consumed in charging by the $EF_{production}$, pursuant to Equation 1, while emissions from stocks are calculated with Equation 2.

[68] BSRIA, the UK, and the European industry association EUROVENT, Brussels. Both companies break down the market for chillers by compressor types and cooling-capacity classes.

Heat pumps with HFCs have been produced and sold since 1995. Since the units have an average service life of 15 years, disposal-related emissions began occurring in 2010. They are calculated with Equation 4.

Emission factors

The emission factors (EF) on which the emissions data are based are listed in Table 152.

The emission factors used are the result of surveys of experts.

The charging loss is 0.5 %. Consequently, the $EF_{production}$ lies within the range given in Table 7.9 of the 2006 IPCC Guidelines, 0.2 to 1 %.

The annual HFC emissions for heating-system heat pumps are estimated at 2.5 %, while the emissions for water-heating heat pumps are placed at 2 %. The EF_{use} used thus lie within the range proposed by the 2006 IPCC Guidelines, 1 to 10 %.

The average lifetime prior to disposal is 15 years, and disposal began in 2010. The system lifetimes used thus lie within the range given in Table 7.9 of the 2006 IPCC Guidelines, 10 to 20 years.

The residual charges in heat pumps, with respect to initial charge, average 75 %. The relevant values given in the 2006 IPCC Guidelines range from 0 to 80 %. The value used is thus a default value.

The recovery factor for heat pumps has been increasing continuously, as a result of the greater care taken in handling refrigerants, and thus the losses occurring upon disposal, with respect to initial charge / residual charge, have been decreasing over the years concerned. The recovery factor was 50 % in 2010, and 54.5 % in 2013. As a result, all of the recovery-factor figures used lie within the range given in Table 7.9 of the 2006 IPCC Guidelines, 0 to 80 %.

Activity data

Each year, the Bundesverband Wärmepumpe (BWP) national heat-pump association publishes the numbers of new heat pumps installed domestically. Those figures serve as the basis for the relevant emissions calculation.

The production / installation ratio used is based on information provided by heat-pump producers.

4.7.1.2.6.4 Heat-pump clothes dryers

Heat-pump clothes dryers with HFC refrigerants have been sold on the German market since 2008. The refrigerants used by these household appliances are HFC-134a and the refrigerant mixture R407C. The charges in the units, which are hermetically sealed, range from 220 g to 485 g.

From 2008 to 2012, one company produced heat-pump clothes dryers charged with the refrigerant HFC-134a. At the end of 2012, that company transferred its production abroad.

The refrigerant model for *heat-pump clothes dryers* is structured similarly to the models for room air conditioners:

- The most important starting values are a) the unit-number figures for domestic sales and domestic production, and b) the split applied to the two refrigerants used (the refrigerant-use figures are tied to the domestic-sales figures). The total numbers of devices are calculated from the sums of new additions.
- Production emissions are calculated by multiplying the quantities consumed in charging by the $EF_{production}$, pursuant to Equation 1, while emissions from stocks are calculated with Equation 2.
- Heat-pump dryers with HFCs have been produced and sold since 2008. Since the units have an average service life of 15 years, disposal-related emissions will begin occurring in 2023.

Emission factors

The emission factors used are based on information from experts. They are listed in Table 152.

The charging loss is 0.5 %. The $EF_{production}$ is country-specific, since the IPCC Guidelines do not cover these appliances.

The ongoing HFC emissions of these hermetically sealed units are estimated at 0.3 %. In this area as well, the IPCC Guidelines provide no specifications.

Activity data

Heat-pump dryers are a relatively new product for which little statistical data and technical information are available. The pertinent refrigerant model is thus based almost exclusively on information provided by manufacturers (cf. SCHWARZ et al., n.y.).

4.7.1.3 Uncertainties and time-series consistency (2.F.1 all)

The emission factors are subject to considerable uncertainties. The broad range of emission factors found in the literature (see the refrigeration models) for identical applications is only partly a consequence of technical modifications, of how well systems are sealed or of national differences. To a large extent, it also results from real uncertainties, since too little solid empirical study of such factors has been carried out (ÖKO-RECHERCHE, 2007).

As a result of the aforementioned uncertainty with regard to emission factors, and to the large number of individual applications (systems) involved, the emissions data are considered to be too imprecise. In order to improve the reliability of data provided, the data were compared with manufacturers' (substance-oriented) sales data.

Until the 2001 reporting year, Germany reported only aggregated emissions, covering all sub-categories. Within the context of emissions surveys for the years 1999 to 2001, and the emissions survey for the 2002 reporting year, the emissions for the reported years 1995 to 1998 were reviewed and updated on the basis of new findings on input quantities and emission factors. All data are thus being improved on an ongoing basis. A comprehensive review of the currentness of the refrigerant models, outset data and emission factors used was carried out in 2012.

The quality of the data on emissions from mobile air conditioning systems is good. The reason for this is that annual HFC consumption can be precisely determined via statistics on registered vehicles and new registrations, and on production, imports and exports of automobiles, which account for the largest part of this sector, as well as via annual model-specific figures for air-conditioner-installation rates and the pertinent charge quantities. Only in the area of commercial vehicles are the data subject to major uncertainties.

The emission factors have been updated on the basis of the results of a study of the Federal Environment Agency (UBA) (SCHWARZ et al., n.y.). In many application areas, the factors show a continuous development throughout the time series. Overall, the EF are considered to be accurate. In the study, the residual charges and recovery factors were determined for all areas of application of refrigeration and air-conditioning systems, in order to achieve conformance with the 2006 IPCC Guidelines.

The uncertainties for the entire sub- category of refrigeration and air conditioning systems have been quantified for the 2014 report.

4.7.1.4 Category-specific recalculations (2.F.1 all)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.7.1.5 Planned improvements (category-specific) (2.F.1)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.7.2 Foam blowing (2.F.2)

Since 1993, hydrofluorocarbons (HFCs) have also been used in foam blowing, as blowing agents substituting for ozone-depleting, climate-damaging CFCs and HCFCs.

A useful distinction can be made between open-cell and closed-cell foam products. In the case of open-cell foam products, the blowing-agent emissions occur only during the production process or immediately after it. The open-cell foam products that are produced and used in Germany include polyurethane integral foam, one-component polyurethane foam and extruded polystyrene hard foam (XPS) blown with HFC-152a. In the case of closed-cell foam products, emissions occur throughout products' entire lifetimes: in production, during use and upon disposal. The products in this category include rigid polyurethane foam, as well as extruded polystyrene hard foam (XPS) blown with HFC-134a or HFC-1234ze. Both types of closed-cell foam products are produced in Germany, with HFCs, and used in Germany.

4.7.2.1 Polyurethane foam products (2.F.2)

4.7.2.1.1 Category description (2.F.2)

Closed-cell polyurethane (PU) hard foam products are used in many different kinds of products, including household appliances, refrigerated vehicles, insulating boards with flexible laminates and sandwich elements with rigid laminates. HFC-134a was used as a blowing agent from 1998 to 2003. Since 2002, HFC-365mfc (with small quantities of added HFC-227ea) has also been used as a blowing agent, and HFC-245fa has also been used as such an agent since 2004. HFC-245ca is not used in Germany. Use of HFC has been decreasing; it is being supplanted by hydrocarbons, such as pentane, and by CO_2 (in small amounts).

The time series, which does not begin until 1998, shows a small increase in emissions until 2003. A larger increase occurred in 2004. These results agree with the historical development of HFC use in this application area, an area which emerged only slowly, in keeping with the long period in which HCFCs were used. Emissions from PUR hard foam products decreased slightly again from 2005 through 2009. A slight increase occurred in 2010, and since then the emissions have remained at a relatively constant level.

4.7.2.1.2 Methodological issues (2.F.2)

The production emissions are calculated, using Equation 1, by multiplying the quantity of HFC that is emitted no later than one year after the time of production (the first-year loss) by the $EF_{production}$. The emissions from stocks are calculated with Equation 2.

Given the products' average lifetime of up to 50 years (sandwich elements), disposal of PU hard foam products will not begin until a few years from now.

Emission factors

The emission factors used are shown in Table 153.

The emission factor for production with HFC-134a is 10 %. That figure is equivalent to the standard value given in the 2006 IPCC Guidelines, in Table 7.6, for "polyurethane continuous panels".

The emission factors for all other HFCs have been approved by national experts and adjusted where necessary. For example, the emission factor for production of PUR hard foam, with use of HFC-365mfc/HFC-227ea as of 2004, was increased from 10 % to 15 %, because that HFC mixture has been used increasingly in open on-site applications, especially in spray foams. The emission factor for production with HFC-245fa is also 15 %. Those values lie within the standard-value range proposed in the 2006 IPCC Guidelines, in Table 7.7, for the "first year loss" for the various PU hard-foam applications.

For PU hard foam blown with HFC-134a, the annual HFC emissions from the "stock" are estimated at 0.5 %. That figure is equivalent to the default value given in the 2006 IPCC Guidelines (Table 7.6) for "polyurethane continuous panels". The products blown with HFC-365mfc/HFC-227ea and HFC-245fa emit 1 % annually, and thus lie within the default-value ranges given by the 2006 IPCC Guidelines, in Table 7.7, for various PU-hard-foam applications. The emission factor used for HFC-365mfc/HFC-227ea emissions from stocks was taken from an estimate based on test products.

Activity data

The figures for new domestic consumption, for each blowing agent and each product group, are based on the amounts of foam products produced in Germany. The data for products in service are based on the amounts of foam products used in Germany (sales in Germany) since the introduction of HFCs. Given a product lifetime of up to 50 years, removals from products in service do not yet play any significant role.

New domestic consumption and domestic sales of foam products are determined annually via surveys of manufacturers, users and blowing-agent suppliers, and via information from the relevant industry association (IVPU – the polyurethane-foam industry association).

4.7.2.2 XPS hard foam (2.F.2)

4.7.2.2.1 Category description (2.F.2)

Extruded polystyrene hard foam (XPS) is used in insulating boards that need to be highly moisture-resistant. HFC consumption and emissions from production of XPS insulation boards have occurred only since 2001, since HCFCs or CO_2 / ethanol were used in this area prior to that time. Since 2001, both HFC-152a and HFC-134a have been used as blowing agents, either singly or in mixtures. Since 2012, HFC-1234ze has also been used as a blowing agent. The emissions behaviour of XPS insulating boards varies in keeping with the blowing agents used to produce them. When HFC-152a is used, HFC emissions occur only during production, and thus the resulting XPS insulating boards can be considered "open-cell" products. When HFC-134a or HFC-1234ze are used, closed-cell XPS hard foam products result that also release HFC emissions during use and disposal.

The relevant time series, which begins in 2001, shows a slightl emissions increase until 2005. As of 2006, the emissions decrease continuously; this is related to the increasing use of non-halogenated blowing agents in production of XPS hard foam products in Germany.

4.7.2.2.2 Methodological issues (2.F.2)

The production emissions are calculated by multiplying the production-related new HFC consumption by the $EF_{production}$, pursuant to Equation 1.

The use emissions are calculated, in keeping with Equation 2 , from the domestic final HFC stocks in XPS insulating materials. Those stocks increase annually solely through new additions of insulating boards containing HFC-134a and HFC-1234ze. Given a product lifetime of 50 years, removals from products in service do not yet play any significant role. The new HFC additions are not equivalent to annual new consumption, minus production emissions. The reason for this is that, as a result of foreign trade, especially exports of XPS products with HFC-134a or HFC-1234ze, only 25 % (the complementary value for the export rate) of the HFC-134a or HFC-1234ze contained in products amounts to new additions to domestic HFC stocks.

Given that XPS insulating boards have an average lifetime of 50 years, disposal will not begin until 2051 at the earliest. Disposal emissions thus play no significant role to date.

HFC-1234ze is reported under "additional greenhouse gases". In keeping with the recommendation in Paragraph 33 of the 2014 UNFCCC Reporting Guidelines, Germany, in addition to reporting on greenhouse gases as required, is also reporting on a number of emissions not subject to reporting obligations. For reasons of confidentiality, those emissions data have been combined with data on other emissions not subject to reporting obligations. They are reported in Chapter (CRF 2.H).

Emission factors

The emission factors used are shown in Table 153.

The production emissions (HFC first-year losses) for HFC-152a are practically 100 % ($EF_{production}$ = 1), since the substance is used solely as a blowing agent in production. With HFC-134a, only part of consumption is emitted upon blowing; most of the substance enters into the product. The $EF_{production}$ for HFC-134a is determined empirically and communicated by the

CEFIC[69] association or by its EXIBA[70] industry association. It is subject to confidentiality requirements. Until experimental measurements become available, the same $EF_{production}$ will be used for XPS insulating boards blown with HFC-1234ze that is used for insulating boards blown with HFC-134a.

Trials with HFC collection and recovery in the production process have been conducted, but to date no relevant systems have been implemented, for both technical and economic reasons.

The 2006 IPCC Guidelines give the following default values, in Table 7.6, for insulating boards blown with HFC-134a and HFC-152a: The "first year loss" is 25 % for HFC-134a and 50 % for HFC-152a. The corresponding values used in Germany, especially that for HFC-152a, differ widely from these figures. At the same time, they are considered to be representative, since they are based on information provided by industry experts.

A representative of the FPX extruded-polystyrene-foam association estimated the annual releases from enclosed HFC-134a cell gas as being less than 1 % in 2002. That figure is based, inter alia, on an internal study of BASF regarding the half-lives of various cell gases, including HFC-134a (WEILBACHER 1987). The EF_{use} from that laboratory study has been used for HFC-134a. Fugitive emissions from boards depend on board thickness, and they can be given only as average values, or as values for specific board thicknesses. The value used, EF_{use} = 0.66 %, is based on average board thickness, and it lies below the value proposed in the 2006 IPCC Guidelines, in Table 7.6, 0.75 %. The 2006 IPCC Guidelines do not provide any default values for insulating boards blown with HFC-1234ze. The same EF_{use} is used for such boards as is used for boards blown with HFC-134a.

Activity data

The new inland consumption of HFC-134a and HFC-152a is reported directly by the European association CEFIC[71] or by its industry group EXIBA[72].

The data on HFC-1234ze are taken from surveys pursuant to the Environmental Statistics Act (Umweltstatistikgesetz).

All of the data required for emissions calculation, including new domestic consumption, loss rate in production and the foreign trade balance for insulation boards containing HFC-134a, are provided by the relevant European industry association (CEFIC or EXIBA).

4.7.2.3 Polyurethane integral foam (2.F.2)

4.7.2.3.1 Category description (2.F.2)

Open-cell polyurethane (PU) integral foams are foams with a porous core and a compact, tough skin. They are produced via reaction injection moulding. In that process, the reaction mixture, including the blowing agent, is injected in liquid form into a cold injection mould. All of the blowing agent is emitted during the foaming action that ensues. PU integral foams are used in the soles of athletic and leisure shoes, in car-body parts and in window profiles. HFCs have been used as blowing agents for production of PU integral foams since 1996.

[69] CEFIC – The European Chemical Industry Council
[70] EXIBA – European Extruded Polystyrene Insulation Board Association
[71] CEFIC – The European Chemical Industry Council
[72] EXIBA – European Extruded Polystyrene Insulation Board Association

Along with HFC-134a, which has been used since 1996, the blowing agents used in Germany also include HFC-365mfc (since 2002; and with minor additions of HFC-227ea) and HFC-245fa (since 2004). HFC-245ca is not used in Germany.

The time series begins in 1996. From then until 2002, the emissions remained relatively constant. From 2002 through 2007, they then increased continuously. HCFCs were long used in production of PU integral foams in Germany, and this delayed the phasing-in of HFCs. A sharp emission reduction occurred beginning in 2008. It was due to intensified use of hydrocarbons (such as pentane), as blowing agents, in place of HFCs.

4.7.2.3.2 Methodological issues (2.F.2)

Pursuant to the 2006 IPCC Guidelines (page 7.34, equation 7.8), the emissions in this open application are considered to be the same as the HFC quantity used in production (new HFC consumption).

The production emissions are calculated by multiplying the production-related new HFC consumption by the $EF_{production}$, pursuant to Equation 1.

No use emissions or disposal emissions occur, since all of the blowing agent is emitted completely in production.

Emission factors

The emission factor used is shown in Table 153.

For PU integral foams blown with HFC-134a, HFC-245fa or HFC-365mfc (with additions of HFC-227ea), the 2006 IPCC Guidelines give a default value of 95 % for the first-year loss. The annual loss is given as 2.5 %, with the result that emissions occur over three years.

According to the in-country experts consulted, all of the blowing agent – except for small residual quantities – escapes during the blowing process. The small residual quantities are then emitted over a period of no longer than two years. For this reason, in a departure from the IPCC Guidelines, Germany considers an emission factor of 100 % to be suitable for production.

Activity data

The figures for new domestic consumption, for each blowing agent and each product group, are based on the amounts of integral foam products produced in Germany.

The new domestic consumption is determined annually via surveys of manufacturers, users and blowing-agent suppliers, and via information from the relevant industry association (IVPU – the polyurethane-foam industry association).

4.7.2.4 One-component polyurethane foam (2.F.2)

4.7.2.4.1 Category description (2.F.2)

The term "one-component foam" refers to open-cell polyurethane foam (PU foam) that is sprayed, on site, from pressurised containers (cans). Such foam is used, for example, in installation of windows and doorframes. The blowing agents now used for such foam, following the prohibition of HCFCs, include mixtures of HFCs and propane, butane or dimethyl ether

(DME). At the same time, the HFC quantities in such cans have been continually reduced since 1996.

HFC-134a has been used in Germany since 1992, in production of PU one-component foam (in cans). HFC-152a was used from 2002 to 2004. Imported cans of PU foam sealant used in Germany contain HFC-134a (since 1992) or HFC-152a (since 1995).

Emissions from PU one-component foams increased sharply from 1992 through 1997. Thereafter, they decreased continuously, until 2010. Since then, they have remained at a low, relatively constant level. Since 4 July 2008, a ban has been in force in the EU, with a few permitted exceptions, on sale of one-component-foam products filled with fluorinated greenhouse gases with a global warming potential (GWP) greater than 150. For that reason, future emissions can be expected to remain relatively constant, at low levels.

4.7.2.4.2 Methodological issues (2.F.2)

The production emissions are calculated from the number of cans filled per year in Germany and the blowing-agent loss per can.

Pursuant to the 2006 IPCC Guidelines (page 7.34, equation 7.8), the emissions in this open application are considered to be the same as the HFC quantity sold in the relevant cans.

Emissions from use are calculated, with Equation 2, via the HFC quantities sold in cans.

No disposal emissions occur, since all of the HFCs in cans of one-component foam are emitted when the cans are used.

Emission factors

The emission factors used are shown in Table 153.

The $EF_{production}$ was determined via surveys of experts and of manufacturers. From 1992 to 2002, it amounted to 1.5 g/can, while since 2003 it has been only 0.5 g/can, since the total fill quantities in cans have decreased.

The 2006 IPCC Guidelines, in Table 7.6, give a first-year loss of 95 % and an annual loss of 2.5 % for one-component foams, with the result that the relevant emissions are distributed over a total of three years in each case. In contrast to the IPCC method, for the German inventory, it is assumed that all emissions occur in the year of sale (EF_{use} = 100 %), since use and disposal occur promptly. At the same time, used cans are not completely empty when they go to waste management; they still contain about 8 % of their original foam contents, including the relevant blowing agent. The majority of that blowing agent eventually also enters the atmosphere, after a certain delay.

Activity data

The data required for determination of the losses from charging (production emissions) – the number of cans charged annually, in Germany, with HFC-134a or HFC-152a, the HFC content per can, in grams, and the specific loss from filling – are obtained via surveys of experts.

The number of cans with blowing agent 134a or 152a that are sold annually in Germany, and the HFC content per can, in grams – i.e. the data required for determination of the emissions from use – are obtained from the producers of cans of one-component foam.

The pre-1995 data for foam sealants were obtained via discussion, in 2006, with leading foreign sellers of one-component foam products and from older publications.

4.7.2.5 Uncertainties and time-series consistency (2.F.2 all)

The uncertainties for the "foams" sub- category have been systematically quantified.

The emissions data for prior years, for PU foam products, are considered fairly accurate, since the quantities of HFCs used are still rather small at present. In future, however, it will become more difficult to obtain a good market overview in view of the anticipated product diversity.

Because it includes only a small number of manufacturers, the German XPS market is not complex. Since the EF and AD were prepared in co-operation with manufacturers, they are considered sufficiently precise.

Since 2001, the relevant industry association has determined, via research, the input quantities of HFC-152a and HFC-134a in production of XPS hard foams. Since only three manufacturers use HFC for XPS blowing, there is little reason to doubt the reliability of the activity data. This also applies to the export rate and the HFC production emissions determined for use of HFC-134a.

The production emissions in use of HFC-152a, 100 %, do not agree with the existing IPCC estimates. Nonetheless, the industry association considers them to be realistic.

The value for the emissions rate from current stocks, as determined by a laboratory study, will be used as long as no reliable measurements with insulation boards in actual service have been carried out; such measurements would be considered more conclusive than laboratory values.

4.7.2.6 Category-specific recalculations (2.F.2 all)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.7.2.7 Category-specific planned improvements (2.F.2 all)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.7.3 Fire extinguishers (2.F.3)

4.7.3.1 Category description (2.F.3)

Halons, which until 1991 were permitted fire extinguishing agents, have since been largely supplanted by ecologically safe substances – especially inert gases, such as nitrogen and argon, for systems for flooding rooms; and by powder, CO_2 and foams in handheld fire extinguishers.

In 1998, HFC-227ea was certified in Germany as a halon substitute. In 2001, HFC 236fa also received such certification. That substance is used solely in the military sector, however. HFC-

23, while certified since 2002, did not begin to be used until 2005. Today, certification of fire extinguishing agents is no longer required. Nonetheless, the list of fire extinguishing agents in use has not grown, since all application areas can be covered with halogen-free agents and with the aforementioned HFCs (especially 227ea and 236fa).

HFC-based fire extinguishing agents are imported and filled into fire extinguishing systems in Germany. Virtually no foreign trade with filled systems takes place. The time series do not begin until after 1995.

4.7.3.2 Methodological issues (2.F.3)

The annual new HFC additions in domestic systems are identical with the amounts added to new systems within the country (new HFC consumption).

Since activity data are available in Germany for HFC-227ea and 236fa, a bottom-up approach is used. Unlike the top-down approach of the 2006 IPCC Guidelines (Chapter 7.6), the bottom-up approach takes emissions from charging into account.

Due to a lack of pertinent data, the installed quantities of HFC 23 are estimated by the Federal Environment Agency.

The figure for the average lifetime of fire extinguishers has been increased from 15 years (*IPCC Guidelines 2006)* to 20 years, in keeping with a consensus of multiple experts.

Emission factors

The $EF_{production}$ are based on experts' assessments.

For HFC-236a, the $EF_{production}$, according to experts' assessments, has to increase from 1 % to 4 % by the year 2007, in order to take account of the greater probability of leaks in older systems. The 4 % figure conforms to the 2006 IPCC Guidelines. The emission factor for use of HFC-23 has also been set at 4 %. With regard to HFC-227ea, concrete figures are available relative to installed and recharged quantities. They were obtained via up-scaling from the pertinent company's market share (as estimated by the company) to the German market as a whole.

The emission factor for disposal is 100 % for all HFCs, although it must be noted that no disposal has yet occurred.

Activity data

The emission figures for HFC 227ea are based on statistical surveys by one company, covering the aspects of input quantities, recharge quantities, accidental releases, releases in cases of fire, and flooding tests in Germany (by analogy to Tier 2). Up-scaling was carried out on the basis of the market shares estimated by the company. The data for HFC-236fa are based on company information provided on a voluntary basis. The figures for HFC-23 are based on estimates of the Federal Environment Agency.

4.7.3.3 Uncertainties and time-series consistency (2.F.3)

The uncertainties for the "fire extinguishing agents" sub- category have been systematically quantified.

4.7.3.4 Category-specific recalculations (2.F.3)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.7.3.5 Planned improvements (category-specific) (2.F.3)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.7.4 Aerosols (2.F.4)

This area includes metered-dose inhalers (MDI), which are used in medical applications, as well as general-purpose aerosols and so-called "novelty aerosols".

4.7.4.1 Metered-dose inhalers (2.F.4.a)

4.7.4.1.1 Category description (2.F.4.a)

Metered-dose inhalers are used in the medical sector, primarily for treatment of asthma. Metered-dose inhalers with an HFC propellant first reached the German market in 1996. They contained the propellant HFC-134a. Beginning 1999, metered dose inhalers with the propellant HFC-227ea were also sold. Since then, the number of available preparations has grown continually. Since 2001, charging of inhalers with HFC-134a has taken place in Germany.

From 1996 through 2002, the time series shows a sharp emissions increase that correlates with increasing use of HFCs as CFC substitutes. A large change occurred in 2001. As of that year, CFCs were prohibited for the largest group of active ingredients, the short-acting betamimetics. Since 2003, the emissions have remained at a relatively constant high level.

4.7.4.1.2 Methodological issues (2.F.4.a)

Since 98 % of the contents of metered dose inhalers consist of propellant, their contents are considered to consist solely of HFCs.

The production emissions are calculated from the number of metered dose inhalers charged per year in Germany and the propellant loss per can. Part of the propellant emissions are collected with cold traps and then incinerated. Without such collection, the emissions would be higher.

Emissions from use are calculated, with with Equation 2, via the HFC quantities sold in metered dose inhalers. The great majority of metered dose inhalers used in Germany are sold in pharmacies. An estimated 10 percent are used by hospitals, for their own needs, while 3 percent are samples, "not for sale", for doctors and pharmaceutical representatives. These two shares are taken into account by adding 13 % to sales by pharmacies.

The time period between pharmacy sales and use is short. The reference figure for the emissions from use – in contrast to the recommendation in the 2006 IPCC Guidelines (equation 7.6) – is thus not the sum of half the purchases (sales) of the previous year and half the purchases (sales) of the current year, but all purchases (sales) for the current year. The approach in the IPCC Guidelines would be a useful choice if the available data covered produced inhalers – rather than sold inhalers – since considerable time, for transport and storage, indeed can pass between production and use.

No disposal emissions occur, since all of the HFCs in metered dose inhalers are emitted when the cans are used.

Emission factors

The emission factors used are shown in Table 153.

The $EF_{production}$ on which production-emissions data are based is itself based on very precise determination of charging emissions, in actual operations, by the only German company that charges such inhalers. These amount to about 1 %, with respect to new consumption for charging. This translates to about 0.15 g per 10 ml inhaler.

In agreement with IPCC specifications (2006 IPCC Guidelines, p. 7.28), a 100 % emissions level in use (EF_{use} = 1) is assumed. Inhaled HFCs are not broken down in bronchial passages; they are released into the atmosphere, without undergoing any changes, upon exhalation. In a departure from the Guidelines, Germany uses a lifetime of only one year for metered dose inhalers. The emission factor has thus been classified as "country-specific".

Activity data

The emissions data for the period until report years 2005 (production) and 2006 (use) are based on sales figures (sales in pharmacies) for metered-dose inhalers in Germany, as obtained via surveys of producers. The total unit numbers, the average charge quantity in ml and the propellant used have all entered into relevant calculations. As of report year 2006, the activity-rate figures for production are based on experts' estimates. As of report year 2007, the activity-rate figures for use are based on such estimates. In the category "metered dose inhalers", the results of the *Federal Statistical Office's* annual surveys of certain climate-relevant substances normally do not become available on time for the corresponding current report year. Retroactive data cross-checking is carried out when necessary, however.

4.7.4.2 Other aerosols (2.F.4.b)

4.7.4.2.1 Category description (2.F.4.b)

In Germany, six types of general-purpose aerosols (includes neither medical metered dose inhalers nor novelties) containing HFC are sold:

- compressed-air sprays,
- cooling sprays,
- drain-opener sprays,
- lubricating sprays,
- insecticides, and
- self-defence sprays.

Production and use of general-purpose aerosols with HFC-134a began in 1992; production and use of such aerosols with HFC-152a began in 1995. From 1992 through 1996, the time series shows a sharp emissions increase that correlates with increasing use of HFCs as CFC substitutes. The emissions remained at a constant level between 1996 and 2005. The emissions then jumped sharply in 2007. Since then, emissions from general-purpose aerosols have been decreasing slightly.

Other aerosols include "novelty" aerosols (artificial snow, "silly string", etc.). Such products are not produced in Germany, however. Use of novelty sprays with HFC-134a began in 1995, while use of sprays with HFC-152a began in 2000. As of 2004, the emissions from such sprays decreased sharply. Since 2010, they have remained at a constant low level. That trend is the result of a EU ban, in force as of 4 July 2009, on sale of novelty aerosols filled with hydrofluorocarbons (HFCs) with a Global Warming Potential (GWP) greater than 150. Producers were quick to respond by choosing other propellants for their products.

4.7.4.2.2 Methodological issues (2.F.4.b)

In the case of general-purpose aerosols, imports and exports are roughly in balance, and thus the domestic market can be considered equivalent to consumption for domestic filling. Domestic consumption refers to spray cans filled in Germany, regardless of where the cans are ultimately used. The production emissions are calculated, pursuant to Equation 1 , from the HFC consumption for in-country filling of general-purpose aerosols and the propellant loss in production.

No novelty aerosols are produced in Germany. The basis for calculating the HFC quantities sold in novelty-aerosol cans consists of the German market's share of the EU market.

Emissions from use are calculated, using Equation 2, via the HFC quantities sold in "other aerosols".

Since the calculations are oriented to the numbers of aerosol cans sold – and not to the numbers produced – the average time period between the sale and use of such cans may be assumed to be very short. The reference figure for calculating the emissions from use – in contrast to the recommendation in the 2006 IPCC Guidelines (equation 7.6) – is thus not the sum of half the purchases (sales) of the previous year and half the purchases (sales) of the current year, but all purchases (sales) for the current year.

Since the HFCs contained in such aerosols are emitted completely when the aerosols are used, no disposal emissions have to be reported.

Emission factors

The EF_{use} = 1.5 % on which production-emissions data for other aerosols are based is itself based on experts' assessments.

A 100 % emissions level in use of other aerosols (EF_{use} = 1) is assumed. This assumption is appropriate, and it accords with the IPCC specifications (2006 IPCC Guidelines, p. 7.28). In a departure from the Guidelines' relevant proposal, it is assumed that all of the cans sold in Germany are used completely in the same year in which they are sold. The emission factor has thus been classified as "country-specific".

Activity data

The data for the period prior to 1995 are based on estimates of experts. In keeping with a bottom-up approach, all quantity data as of 1995 are provided directly by producers, fillers and operators, as well as by relevant industry associations. Emissions data for general-purpose aerosols also include filling emissions (= production emissions). Estimates are based on EU-wide data.

4.7.4.3 Uncertainties and time-series consistency (2.F.4 all)

The uncertainties for the "aerosols" sub- category have been systematically quantified.

In the case of metered dose inhalers, the surcharge factor for hospitals and doctors' samples can vary, by ± 3 %, from the above-cited 13%.

In comparison to the emissions data for metered dose inhalers, the data for other aerosols are considered not as good, since the large number of products involved makes it difficult to obtain an overview of the market. Large quantities of imports, especially in the area of "novelties", also complicate the situation. The uncertainties are thus considerably higher (more than 20 %).

Since the shift from CFCs to chlorine-free propellants had already been completed by the beginning of the 1990s, the time series for the period 1995-2005 showed virtually no changes. Slight emissions decreases have been seen since 2006.

4.7.4.3.1 Category-specific recalculations (2.F.4 all)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.7.4.3.2 Category-specific planned improvements (2.F.4 all)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.7.5 Solvents (2.F.5)

4.7.5.1 Category description (2.F.5)

Use of HFCs as solvents was banned in Germany until the year 2001 (2nd Ordinance on the Implementation of the Federal Immission Control Act – 2. BimSchV) and remains heavily restricted to this day. A separate permit has to be applied for for every surface-treatment facility that uses HFCs either in a pure form or in mixtures with trans-1,2-dichloroethene, and such permits are granted only in special cases. In addition to HFC-4310mee, which has already been reported, HFC-245fa, HFC-245fa and C_6F_{14} are now also used, in very small quantities.

4.7.5.2 Methodological issues (2.F.5)

Emissions are calculated in keeping with Tier 2a as described in the 2006 IPCC Guidelines (Chapter 7.2).

Emission factors

Emissions in use are assumed to be completed within 2 years.

Activity data

The consumption figures for HFC-4310mee are based on the sales data of an authorised dealer. The quantities of HFC-245fa, HFC-365mfc and C_6F_{14} used are based on information provided by industry experts. Since the data are confidential, they are reported under CRF 2.H.

4.7.5.3 Uncertainties and time-series consistency (2.F.5)

All of the uncertainties for the sub- category *solvents* have been identified.

4.7.5.4 Category-specific recalculations (2.F.5)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.7.5.5 Category-specific planned improvements (2.F.5)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.7.6 Other applications that use ODS substitutes (2.F.6)

Germany reports no emissions in this category.

4.7.7 Category-specific QA/QC and verification (2.F all)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The data for the 2003 report year, like the data for most of the previous years, were collected by an external expert working in the framework of a research project under commission to the Federal Environment Agency.

For the most part, quality assurance was carried out by an external expert. In addition, the data are checked by the relevant Federal Environment Agency specialists upon receipt.

The collected data on the size of category-specific HFC stocks, on composition of those stocks with regard to various HFC refrigerants, on EF, etc. are subject to continual quality assurance / control and verification, although this process has not yet been standardised. On a regular basis, various sources (environmental statistics[73], production and sales figures[74], etc.) are consulted, and experts (users, refrigerant manufacturers, suppliers, etc.) are consulted to determine the sources' reliability.

In 2011, the entire sector of F-gas emissions was subjected to voluntary trilateral review. Experts from England, Germany and Austria reviewed "each other's" F-gas inventories. The aims of the review were to exchange information regarding country-specific methods for preparing F-gas inventories; to learn about the institutional and legal regulations for F-gas

[73] Surveys pursuant to Art. 11 of the Environmental Statistics Act (UstatG).
[74] Surveys pursuant to the Foreign Trade Statistics Act (AHStatGes) and production statistics.

inventories in each country; to identify obstacles for the preparation of complete, precise inventories; and to discuss differences and similarities between the various methods used to prepare F-gas inventories. The meeting helped all three countries to review their methods for relevant emission calculation. In addition, the transparency, completeness and precision of the various inventories were assessed. That review had a positive outcome, namely that Germany has a good F-gas inventory. As a result, no recommendations were issued for improvements of the German F-gas inventory.

4.8 Other product manufacture and use (2.G)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T	**2.G Other product manufacture and use**		**SF6**	**6,072.2**	**(0.50%)**	**3,107.6**	**(0.33%)**	**-48.8%**
-/T	**2.G Other product manufacture and use**		**N_2O**	**C**	**C**	**C**	**C**	**C**
-/-	2.G Other product manufacture and use		CH_4	4.5	(0.00%)	36.0	(0.00%)	694.8%
-/-	2.G Other product manufacture and use		HFC	0.0	(0.00%)	7.1	(0.00%)	-
-/-	2.G Other product manufacture and use		PFC	0.0	(0.00%)	0.0	(0.00%)	-

Gas	Method used	Source for the activity data	Emission factors used
CO_2, CH_4, N_2O, SF_6, PFC, HFC	cf. Table 154	cf. Table 154	cf. Table 154

The category *Other product manufacture and use* is a key category for SF_6 emissions in terms of level and trend. For N_2O emissions, it is a key category only in terms of trend.

The category 2.G includes SF_6 from electrical equipments (2.G.1), SF_6 and PFC from other product use (2.G.2), use of N_2O (2.G.3), other ORC systems (2.G.4 ORC) and CO_2, CH_4, N_2O and particulate emissions from use of charcoal (2.G.4 Charcoal). In the interest of more-precise data collection, these sub- categories are further divided, to some extent, in the following section.

The methods, emission factors and applicable lifetimes on which the emission calculation is based are listed in Table 153.

Table 154: Overview of the methods and emission factors used, for the current report year, in the categories 2.G.1 (Electrical equipments), 2.G.2 (SF_6 and PFC from other product use) and 2.G.4 (ORC systems & charcoal use)

	QG	Method	Gas			Lifetime	Emission factor (dimensionless)		
			SF_6	HFC	PFC	[years]	Production	Application	Waste management
1. Electrical equipments	**2.G.1**								
Switchgear and controlgear	2.G.1a	Tier 3a	SF_6				0.02 (CS)	0.001 – 0.01 (CS)	0.015 (CS)
2. SF_6 and PFC from other product use	**2.G.2**								
AWACS	2.G.2a	CS					NO	C	NO
Particle accelerators	2.G.2b	CS	SF_6				0.15 - 1 (CS)	0.006 – 0.003 (CS)	NO
Insulated glass windows	2.G.2c	Equ. 3.24 ff					0.33 (D)	0.01 (D)	1 (D)
Adiabatic behaviour	2.G.2d								
- Automobile tyres		Equ. 3.23	SF_6				NO	NO	1 (D)
- Athletic shoes		Equ. 3.23	SF_6		PFC		NO	NO	1 (D)
Other	2.G.2e								
- Trace gases		Equ. 3.22	SF_6				NO	1 (D)	NO
- Welding		CS	SF_6				NO	1 (CS)	NO
- Optical glass fibre		CS	SF_6				0.7 (CS)	NO	NO
- Medicines and cosmetics		CS			PFC	-	NO	1 (CS)	NO
4. Other	**2.G.4**								
ORC systems	2.G.4a	CS		HFC	PFC	20 – 30 (CS)	0.02 (CS)	0.04 (CS)	0.2 (CS)
Charcoal use	*2.G.4b*	*Confidential*							

4.8.1 Electrical equipments (2.G.1)

This category consists primarily of use of electrical equipments (2.G.1), which is further sub-divided into high-voltage (HS – Hochspannungs-), medium-voltage (MS – Mittelspannungs-) and other electrical equipments.

4.8.1.1 Category description (2.G.1)

In electricity transmission and distribution, SF_6 is used primarily in switchgear and controlgear and equipment in high-voltage (52-380 kV) and, increasingly, medium-voltage (10-52 kV) networks. It serves as an arc-extinguishing and insulation medium (in the latter function, in place of air). In addition, it is used in production of components installed in gas-insulated indoor switchgear and controlgear (instrument transformers, bushings) or supplied directly to operators (high-voltage instrument transformers for outdoor installations).

As a result of first-time inclusion, in report year 2002, of additional SF_6 applications, the time series shows a marked jump in emissions in 2002. In report year 2005, new companies were included in reporting, especially in the new category "Other electrical equipments". For reasons having to do with the economy as a whole, more systems were sold in 2005 and 2006. Nonetheless, absolute emissions are falling overall, due to considerable reductions in the area of "other" equipments and as a result of again-lower emissions rates in switchgear and controlgear. In 1996, industry, represented by producers' and operators' associations and the SF_6 producer, committed itself to reducing emissions in life cycles of switchgear and controlgear and to provide annual progress reports. In 2005, this voluntary commitment was extended, in co-operation with the Federal Environment Agency and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), to include additional energy-transmission and energy-distribution installations above the 1 kV level. In addition, specific reduction targets were added to the commitment. The scope of voluntary reporting was enlarged and refined accordingly. In subsequent years, manufacturers and the gas producer made further investments in reduction measures. Substitutes for SF_6 foams were introduced in some sub-areas of bushings. This brought about further reductions in specific emissions rates and absolute emissions, even though production continued to increase.

4.8.1.2 Methodological issues (2.G.1)

The emissions figures are based largely on a mass balance. Increasingly, they are also being combined with emission factors for sub-areas in which the technical measurement limits for mass-balancing have been reached or in which mass-balancing would necessitate unreasonably high costs.

The methods used are based on the new "2006 IPCC Guidelines for National Greenhouse Gas Inventories; Volume 3", Chapter 8. For further information, the reader is referred to "Tier 3, Hybrid Life-Cycle Approach" in sub-chapter 8.2.

Usage emissions

Ongoing emissions from stocks are based on the stocks of SF_6 that have accumulated since 1970, via annual additions of switchgear and controlgear, and that are in place as of the middle of a relevant year n.

The final stocks of SF_6 in all electrical equipments for a given year n change annually by the balance of new additions and removals. Some removals (high voltage) have been registered since 1997; large-scale removals of first-generation high-voltage switchgear and controlgear and equipment cannot be expected until after 2015, in light of the products' estimated service lifetime of at least 40 years.

Three special aspects must be taken into account in reporting relative to switchgear and controlgear:

- Calculation of the final stocks for a given year n is based on the final stocks for the previous year (n-1); this does not extend back to the first year of service, however. Such backward extension, an otherwise customary procedure, is not used for switchgear and controlgear, because operators/manufacturers estimated the SF_6 stocks in service for 1995. Their estimate was broken down into high-voltage and medium-voltage categories (770 t and 157.6 t, respectively).
- In the area of high-voltage switchgear and controlgear, stocks and emissions are determined via direct surveys of the some 100 operators. In such surveys, the operators are asked to provide data on their current stocks of SF_6 in electrical equipments (gas-insulated HV switchgear (GIS), circuit breakers, outdoor instrument transformers). Emission factors determined on the basis of reference systems are then applied to such stocks data.

- The group of operators of medium-voltage switchgear is very numerous and highly diverse. It is thus not feasible to conduct direct surveys. Manufacturers of medium-voltage switchgear have themselves taken responsibility for updating their domestic stocks data on the basis of their sales data. The emissions can be determined in that the systems are practically maintenance-free and, by definition (IEC 62271-1), require no refilling throughout their entire lifetimes. The emissions are minimal (usually, they occur only as a result of external influences), and they can be accounted for via a lump-sum emission factor (obtained via surveys of experts); the emissions rate has been set at a constant 0.1 % since 1998, since virtually all of the systems added to domestic stocks since the mid-1990s are systems that are "sealed for life" (hermetically sealed pressurised systems pursuant to IEC). In their voluntary commitment of 2005, the operators also promised to use only such systems. As a result, the impact of the few older systems that have emissions rates greater than 0.1 % has diminished. The stocks are calculated on the basis of the previous year's stocks, plus new deliveries and less decommissioned systems.

Disposal emissions

Because switchgear and controlgear have long service lifetimes (40 years), and because the first use of SF_6 dates from the late 1960s, disposal emissions were very low until 2004. For the period until 2004, therefore, the quantities of SF_6 (AD), in old switchgear and controlgear (high-voltage and medium-voltage), that were slated for disposal have been roughly estimated (at a constant 3 t/a). As of the 2005 report year, amounts for disposal from systems removal were determined precisely for the first time, by the relevant associations. This also applies to emissions from disposal, which prior to 2005 were estimated at 0.06 t.

Activity data

In the framework of the manufacturers' voluntary commitment, annual consumption by manufacturers of electrical equipments, and stocks of medium-voltage switchgear and controlgear, are reported to the Federal Environment Agency by the German Electrical and Electronic Manufacturers' Association (ZVEI), while stocks of high-voltage switchgear and controlgear, outdoor-mounted instrument transformers, gas-insulated lines and transformers are reported by the Forum network technology / network operation (FNN) in the Association for Electrical, Electronic & Information Technologies (VDE) and, since 2004, by the Association of the Energy and Power Generation Industry (VIK). Participants in the voluntary commitment jointly determine quantities of decommissioned units.

Table 155 shows the inventory data for the current year, broken down by sub- categories and with explanatory remarks. The sum total for electrical equipments for energy transmission and distribution agrees with the data in Table 2 (II)F, Sheet 2, category 2.G.1 in the CRF.

Table 155: 2013 inventory data for category 2.G.1, including relevant sub- categories

Category 2.G.1: Electrical equipments for energy transmission and distribution	Activity data			Emissions	
	Annual consumption , production	Stocks	Decommissioned	Production	Operation
	(tonnes of SF_6)				
Electrical equipments for energy transmission and distribution 2.G.1 (total), including:	802	2,293	10.4	11.1	6.3
MV switchgear and controlgear *	164	1,027	0.3	0.5	1.0
HV switchgear and controlgear **	542	1,047	10.1	2.8	4.7
Other electrical equipments ***	96	218	IE	7.7	0.6

IE= included in "HV switchgear and controlgear; marginal

Explanatory remarks:

* Hermetically sealed pressurised systems pursuant to IEC 62271-1 for the range 1kV through 52 kV; also known as "sealed for life" systems

** Sealed pressurised systems pursuant to IEC 62271-1 for the range above 52 kV

*** Gas-insulated transformers: marginal residual stocks in the network; (no production emissions) + high-voltage instrument transformers for outdoor installation (all emissions categories) + gas-insulated lines (GIL) (all emissions categories) + high-voltage bushings (only production emissions) + medium-voltage cast-resin instrument transformers (only production emissions) + testing of medium-voltage components (only production emissions) + 1000V capacitors (only production emissions)

4.8.1.3 Uncertainties and time-series consistency (2.G.1)

Since there are only about ten different manufacturers of electrical equipments (including bushings and instrument transformers), the consumption data, and the new-additions and decommissioned-units figures, are highly reliable. This holds all the more in that such data and figures are based on internal accounting, and that fill amounts are determined with great precision and then noted on devices' name plates. The pertinent uncertainty is in the area of ± 5 %.

Determination of emissions is more difficult, since the plants typically concerned have several different emissions sources, each quite small. Gas losses occur in filling of devices, in testing, in opening of products that fail to pass quality inspections, in product development, etc.. On the other hand, all domestic plants proceed in accordance with a standardised questionnaire that lists all possible emissions sources and that is checked for correctness during surveys. For this reason, and because there are few manufacturers (see above), the precision of data collection ultimately depends on the precision of the relevant measurements. The resulting figures lie within ±10 % of estimates.

Emissions from operations in the high-voltage sector are determined by selected operators, via monitoring of annual refilling of reference systems (refills are carried out when levels fall below 90 % of the desired fill level, and the devices themselves normally display such fill requirements as soon as they occur). This method can be considered very reliable, i.e. the deviations from the actual value are about ±5 %. All surveys to date have produced similar results for emissions rates; all results are within a range from 0.55 to 0.88 %. The one-time emissions-rate peak for high-voltage switchgear and controlgear that occurred in 2004 is the result of special events. In the main, it was due to simultaneous refilling of old, older-model systems that were less well-sealed.

In the year 2000, a decrease with respect to the previous year occurred in high-voltage in-service stocks and, thus, in emissions, both of which had been increasing since 1995. For in-service stocks, the decrease amounted to over 25 t, while for emissions it amounted to 0.85 t. That decrease, which was due to trends in gas-insulated HV switchgear (GIS) (600 to 567 t), cannot be explained as the result of decommissioning removals, since the role of such removals is still insignificant. According to the association of network operators (VDN), which carried out the surveys at the time, the underlying problem is both statistical and organisational in nature. At the end of the 1990s, electricity-market liberalisation led to profound operator regrouping (through mergers and changes in ownership of various parts of companies). Along with those changes, personnel assignments relative to electrical equipments in service were repeatedly changed. As a result, it is possible that double-counting occurred in 1999, and that some operating equipment was not counted in 2000. In light of experience gained in recent years, the uncertainty today can be assumed to lie in the range of ± 5 % for high-voltage stocks.

Pursuant to the IEC, the emissions rate of 0.1 % in the medium-voltage sector is a normal rate for hermetically sealed pressurised systems.

4.8.1.4 Category-specific recalculations (2.G.1)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.8.1.5 Category-specific QA / QC and verification (2.G.1)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The data for the 2003 report year, like the data for most of the previous years, were collected by an external expert working in the framework of a research project under commission to the Federal Environment Agency.

For the most part, quality assurance was carried out by an external expert. In addition, the data are checked by the relevant Federal Environment Agency specialists upon receipt.

In 2011, the entire sector of F-gas emissions was subjected to voluntary trilateral review. Experts from England, Germany and Austria reviewed "each other's" F-gas inventories. The aims of the review were to exchange information regarding country-specific methods for preparing F-gas inventories; to learn about the institutional and legal regulations for F-gas inventories in each country; to identify obstacles for the preparation of complete, precise inventories; and to discuss differences and similarities between the various methods used to prepare F-gas inventories. The meeting helped all three countries to review their methods for relevant emission calculation. In addition, the transparency, completeness and precision of the various inventories were assessed. That review had a positive outcome, namely that Germany has a good F-gas inventory. As a result, no recommendations were issued for improvements of the German F-gas inventory.

4.8.1.6 Category-specific planned improvements (2.G.1)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.8.2 *SF_6 and PFC from other product use (2.G.2)*

This category comprises the applications *Military AWACS* (2.G.2.a), *Particle accelerators* (2.G.2.b), *Sound-proof glazing* (2.G.2.c), *Adiabatic properties: Automobile tyres* and *athletic shoes* (2.G.2.d), Other: *Trace gas, welding, optical glass fibres* and medical and cosmetic applications (2.G.2.e).

4.8.2.1 Military AWACS maintenance (2.G.2.a)

4.8.2.1.1 Category description (2.G.2.a)

SF_6 is used as an insulating medium for radar in Boeing E-3A (NAEWF; formerly, AWACS) aircraft, which are large military surveillance aircraft. It is used to prevent electrical arcing, towards the antenna, in waveguides with high voltages in excess of 135 kV. Ongoing emissions are relatively high, since SF_6 is released to equalize pressure as aircraft climb.

4.8.2.1.2 Methodological issues (2.G.2.a)

The emissions figures are based on reported purchased quantities for filling and refilling of NATO's NAEWF fleet. Reported sales figures are double-checked against gas-sellers' statistics. The emissions data for report years until 2001 are based on estimates that are themselves based on a survey from the year 1996. For this reason, the emissions data for the years 1997 to 2001 are imprecise. For report year 2002, a new survey of consumed quantities was carried out. This showed a significant increase over relevant quantities in report year 2001.

Experts consider the annual SF_6 requirements for the NAEWF fleet to be constant.

Data on AWACS maintenance are reported under CRF 2.H, since the data are confidential.

4.8.2.2 Particle accelerators (2.G.2.b)

4.8.2.2.1 Category description (2.G.2.b)

SF_6 is used in elementary particle accelerators as an insulating gas. High-voltage accelerator systems (0.3 to more than 23 MV) are used by university institutes, research groups and industry. In industry, low-voltage devices with less than 0.3 MV are also used. Yet another relevant category consists of radiation-therapy devices in medical facilities.

4.8.2.2.2 Methodological issues (2.G.2.b)

In early 2004, Öko-Recherche, working under commission to the Federal Environment Agency, carried out a complete survey of particle accelerators within the country, with the aim of updating pertinent data, some of which date from 1996. In the process, both users and producers of the devices/systems were queried. The questions posed had to do with the quantities of SF_6 in their devices and with refills of SF_6 carried out during the last seven years.

The CSE assumes responsibility for structuring the survey. For all five relevant categories, it contains annual data on SF_6 stocks and on replacements to compensate for emissions. The emissions in question include both ongoing emissions and minor filling and disposal losses.

For the 2011 report year, another exhaustive survey was carried out out. For the first time, data on electron microscopes were gathered. (Öko-Recherche 2013)

4.8.2.2.3 Uncertainties and time-series consistency (2.G.2.b)

The uncertainties for this category have been systematically quantified.

4.8.2.2.4 Category-specific recalculations (2.G.2.b)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.8.2.3 Category-specific quality assurance / control and verification (2.G.2)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The data for the 2003 report year, like the data for most of the previous years, were collected by an external expert working in the framework of a research project under commission to the Federal Environment Agency.

For the most part, quality assurance was carried out by an external expert. In addition, the data are checked by the relevant Federal Environment Agency specialists upon receipt.

In 2011, the entire sector of F-gas emissions was subjected to voluntary trilateral review. Experts from England, Germany and Austria reviewed "each other's" F-gas inventories. The aims of the review were to exchange information regarding country-specific methods for preparing F-gas inventories; to learn about the institutional and legal regulations for F-gas inventories in each country; to identify obstacles for the preparation of complete, precise inventories; and to discuss differences and similarities between the various methods used to prepare F-gas inventories. The meeting helped all three countries to review their methods for relevant emission calculation. In addition, the transparency, completeness and precision of the various inventories were assessed. That review had a positive outcome, namely that Germany has a good F-gas inventory. As a result, no recommendations were issued for improvements of the German F-gas inventory.

4.8.2.3.1 Category-specific planned improvements (2.G.2.b)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.8.2.4 Sound-proof glazing (2.G.2.c)

4.8.2.4.1 Category description (2.G.2.c)

Since 1975, SF_6 has been used to enhance the soundproofing properties of multi-pane windows. In such use, the gas is inserted into the spaces between the panes. The disadvantages of such use are that it reduces windows' thermal-insulation performance and that SF_6 is a powerfully acting greenhouse gas. The higher priority given to thermal insulation – e.g. by the Thermal Insulation Ordinance (Wärmeschutzverordnung) – along with improved SF_6-less window technologies, have led to a reduction in use of SF_6 in this application since the mid-1990s.

In Germany, sound-proof windows have been produced by numerous companies and filled with gas. Exports of assembled windows play no significant role.

Since 4 July 2007, a ban has been in force in the EU on sale of windows, for residential uses, that are filled with fluorinated greenhouse gases. As of 4 July 2008, that ban also applies to other windows. Current and future emissions in this category thus come primarily from open waste management of old windows, which is assumed to occur an average of 25 years after the windows were filled. For this reason, total emissions are expected to continue growing until the year 2020.

4.8.2.4.2 Methodological issues (2.G.2.c)

Emissions occur during filling of spaces between panes, as a result of overfilling (production emissions), during use (use emissions) and in disposal (disposal emissions). Emissions are calculated in keeping with with equations 3.24 – 3.26 of IPCC-GPG (2000) on the basis of new domestic consumption, average annual stocks and remaining stocks 25 years ago.

The time series for sound-proof glazing begin in 1975, since the filling quantities of the year 1975 are of relevance for emissions from stocks in 1995. These data, which were reconstructed with the help of industry experts in 1996, were published in 2004 for the first time.

Emission factors

According to expert-level information from manufacturers of windowpanes and gas-filling equipment, provided to industry experts and to a scientific institute, one-third of the SF_6 used in the process of pumping SF_6 into spaces between windowpanes escapes. The $EF_{production}$ is thus 33 %, with respect to new annual consumption.

This emission factor is obtained in the following manner: In use of both manual filling devices and automatic gas-filling presses, gas-swirling in the space between the panes cannot be avoided. As a result, the escaping gas consists not only of the air originally between the panes, it also includes an air-SF_6 mixture. More and more mixed gases escape as the filling process progresses. The gas loss, the "overfill", ranges from 20 to 60 % of the amount filled. The smaller the window concerned, the greater the overfill's relative importance. On average, i.e. throughout the entire spectrum of filled windows, of all shapes and sizes, the overfill level amounts to 50 % of the amount actually contained between the panes. This corresponds to one-third (33 %) of the relevant consumed amounts. This emission factor continues to be used, since neither filling technologies nor the range of window geometries have changed.

A DIN standard (DIN EN 1279-3, DIN 2003) specifies an upper limit of 10 per mil for annual losses of filled gas from panes' peripheral seals. This value also takes account of gas losses resulting from glass breakage in transport, installation and use, as well as from age-related increasing leakage from peripheral seals. The result is an emission factor EF_{use} of 1 % with respect to the average SF_6 stocks that have accumulated since 1975 and that are in place in year n.

Finally, disposal losses are incurred at the end of windows' service lifetimes (utilisation periods), or an average of 25 years after the windows were filled. For this reason, emissions from disposal do not have to be taken into account until the year 2000.

Since each year a window loses 1 % of its gas, with respect to the previous year's value, only part of a window's original quantity of gas is emitted when the window undergoes disposal. Since no gas collection upon disposal takes place, however, the emissions level is 100% ($EF_{disposal}$ = 1).

Activity data

The new annual consumption was determined via top-down survey (domestic sales by the gas industry).

4.8.2.5 Adiabatic behaviour – Automobile tyres (2.G.2.d)

4.8.2.5.1 Category description (2.G.2.d)

Beginning in 1984, automobile tyres were filled with SF_6 for reasons of image (the resulting improved pressure constancy is not relevant in practice). The peak consumption year was 1995. In that year, over 500 of the some 3,500 tyre-sales outlets in Germany had equipment for filling tyres with SF_6 gas. Because SF_6 is a powerfully acting greenhouse gas, many tyre dealers began filling tyres with nitrogen instead. This practice led to a considerable reduction in use of SF_6. Since 4 July 2007, a ban has been in force in the EU on sale of new automobile tyres filled with fluorinated greenhouse gases. The bulk of today's emissions originates from gas in older filled tyres.

4.8.2.5.2 Methodological issues (2.G.2.d)

For the sake of simplicity, gas emissions during tyres' service lifetimes are not taken into account; as a result, emissions occur only when tyres are dismantled. Given an intended service lifetime of about 3 years, and the fact that there is no foreign trade with filled types, emissions follow domestic consumption for filling with a three-year time lag (ÖKO-RECHERCHE, 1996). The emissions are calculated using equation 8.9 of the 2006 IPCC Guidelines.

Emission factors

The very small losses incurred in filling of tyres are not taken into account. Since SF_6 escapes completely when tyres are dismantled, $EF_{disposal}$ = 1.

Activity data

Annual sales have been determined via surveys, carried out by the Federal Statistical Office, of gas suppliers, regarding their domestic sales to tyre dealers and automobile service centres.

4.8.2.6 Adiabatic behaviour – Athletic shoes (2.G.2.d)

4.8.2.6.1 Category description (2.G.2.d)

SF_6 was inserted into the soles of sport shoes in order to enhance cushioning. 2003 was the last year in which this practice occurred anywhere in Europe. As of 2004, PFC-218 (C_3F_8) was used in this application. Use of that gas was then discontinued in 2006. Today, nitrogen is usually used for this purpose. The sale of footwear produced with fluorinated greenhouse gases has been prohibited in the EU since 4 July 2006. Current emissions occur only in disposal of sport shoes.

4.8.2.6.2 Methodological issues (2.G.2.d)

The emissions are calculated using equation 8.9 of the 2006 IPCC Guidelines. Production emissions occur only in foreign countries. Current emissions from stocks are not determined. In keeping with a commitment to maintain confidentiality, data relative to athletic-shoe soles are reported under CRF 2.G.

Emission factors

Manufacturers do not report production emissions.

It is assumed that no emissions occur during use.

In disposal, emissions may be equated with input quantities ($EF_{disposal}$ = 1). In addition, in a procedure similar to the IPCC method for automobile tyres, a time lag of three years is assumed.

Activity data

The filled quantities are based on manufacturers' European-wide sales figures. These figures are broken down, on the basis of Germany's population, to obtain figures for Germany. While such data have been available to the Federal Environment Agency since the 2001 report year, for reasons of confidentiality they are reported only in aggregate form, under CRF 2.H.

4.8.2.7 Other: Trace gas (2.G.2.e)

4.8.2.7.1 Category description (2.G.2.e)

SF_6, as a stable and readily detectable trace gas, even at extremely low concentrations, is used by research institutions to investigate a) ground-level and atmospheric airflows and gas dispersions and b) water currents.

As of report year 2007, use of SF_6 as a trace gas decreased considerably with respect to earlier years.

4.8.2.7.2 Methodological issues (2.G.2.e)

The quantities used are estimated by experts.

Emission factors

An "open use" is assumed, i.e. annual new inputs are completely emitted in the same year and are treated as consumption for production ($EF_{production}$ = 1). No recovery takes place.

Activity data

In 1996, total domestic use was estimated by experts of all relevant research institutions. Since then, use levels have been estimated by one expert at three-year intervals. These assessments indicate that the quantities used vary only slightly.

4.8.2.8 Other: Welding (2.G.2.e)

4.8.2.8.1 Category description (2.G.2.e)

According to gas suppliers, use of SF_6 in welding began in 2001. SF_6 is used as a protective gas in welding of metal. Since there is only one user in Germany, the pertinent data are subject to confidentiality protection.

4.8.2.8.2 Methodological issues (2.G.2.e)

Because they are confidential, data on consumption and emissions in connection with welding are reported under CRF 2.H.

Emission factors

No reliable data are available on SF_6 decomposition during use. Experts presume that the entire relevant input SF_6 quantities are emitted completely into the atmosphere during use. For this reason, consumption and emissions are considered equal for welding applications. The emission factor for welding is specified as $EF_{use} = 1$.

Activity data

The annual amounts consumed are determined via enquiry of the company that uses SF_6 for welding purposes.

4.8.2.9 Other: Optical glass fibre (2.G.2.e)

4.8.2.9.1 Category description (2.G.2.e)

Use of SF_6 in production of optical glass fibre began in 2002. In such production, SF_6 is used for fluorine doping. Numerous production operations are in place in Germany.

4.8.2.9.2 Methodological issues (2.G.2.e)

Emissions occur in production of optical glass fibre cable.

Emission factors

The 2006 IPCC Guidelines[75] contain no information on use of SF_6 in production of optical glass fibre. According to experts, 70 % of the input SF_6 quantities escape. For this reason, an emission factor of $EF_{production} = 0.7$ is used.

Activity data

The annual consumption figures are obtained via surveys, carried out by the Federal Statistical Office, of gas suppliers, with regard to their domestic sales.

4.8.2.10 Other: Medical and cosmetic applications (2.G.2.e)

4.8.2.10.1 Category description (2.G.2.e)

In Germany, fluorinated greenhouse gases, in addition to being used in medical metered dose inhalers (category 2.F.4), are also used in various medical and cosmetic applications.

[75] IPCC GL 2006, Vol. 6, Chapter 6: Electronics Industry

Since 2000, perfluorodecalin ($C_{10}F_{18}$, PFC-9-1-18) has been used, in pure form, in ophthamology and in research. In ophthamology, perfluorodecalin is used in retinal surgery within the eye, especially in treatment of retinal detachments, retinal tears, proliferative vitreoretinopathy, etc.. Perfluorodecalin is also used, in considerably smaller quantities, in research into organ preservation during transplants, as a contrast agent in diagnostic imaging techniques (magnetic resonance tomography, ultrasound) and as an oxygen carrier in cell cultivation.

Since 2012, perfluorodecalin has also been used as an ingredient in cosmetic products (skin care; nail care). In such products, it serves as a carrier or storage medium for oxygen. The perfluorodecalin concentrations used in such products, according to manufacturers, amount to 0.1 %.

In Germany, hydrofluoroethers (HFE) are the standard anaesthetic gases used for inhalative anaesthesia. They are used in some 7 million operations annually. Isoflurane, a halogenated ether (HCFE-235da2, CHF_2-O-CHCl-CF_3), has been used since 1985. Desflurane (HFE-236ea2, CHF_2-O-CHF-CF_3) and sevoflurane (HFE-347mmz1, CH_2F-O-$CH(CF_3)_2$, which have been used since 1995, currently have a combined market share of about 90 %. In relevant uses, the hydrofluoroethers are vaporized in special equipment. They are administered in concentrations of 1 % to 6 % in a carrier gas consisting of oxygen and nitrous oxide (N_2O). On average, 20 g to 25 g of hydrofluoroethers are used per operation.

As recommended by the 2006 IPCC Guidelines, medical and cosmetic applications of PFCs are placed in category 2.G.2. Emissions of hydrofluoroethers, which are not subject to reporting obligations, are reported voluntarily, as "additional greenhouse gases". In keeping with the recommendation in Paragraph 33 of the 2014 UNFCCC Reporting Guidelines, in addition to reporting on greenhouse gases as required, Germany is reporting on a number of emissions not subject to reporting obligations. For reasons of confidentiality, those emissions data have been combined with data on other emissions not subject to reporting obligations. They are reported in Chapter (CRF 2.H).

4.8.2.10.2 Methodological issues (2.G.2.e)

In ophthamological and research applications in which it is used in pure form, all of the perfluorodecalin used is emitted. The perfluorodecalin in cosmetic products is also emitted completely when the products are used.

Hydrofluoroethers, when used as inhalation anaesthetics for surgeries, are exhaled by patients during the operation, without being changed. As a result, the pertinent emissions occurring in a given year may be considered equal to the total quantities used in the year for such applications.

No production emissions occur in the case of medical and cosmetic applications, since no relevant products are produced in Germany.

In the case of perfluorodecalin, the emissions from use are calculated, using Equation 2, via the quantities of perfluorodecalin sold in bulk and in cosmetic products. In a departure from the method proposed by the 2006 IPCC Guidelines for calculation of "prompt emissions" (equation 8.23), it is assumed that all of the quantities sold in a given year are emitted completely in the same year, i.e. the emissions are not calculated as the sum of half the purchases (sales) of the previous year and half the purchases (sales) of the current year. This approach is justified in that the time between sale and use tends to be very short.

Emissions from use of hydrofluoroethers used as anaesthetic gases are calculated with Equation 2, via the quantities used in Germany. The 2006 IPCC Guidelines provide no instructions for calculating such emissions.

Since the perfluorodecalin and the hydrofluoroethers are emitted completely when used, no disposal emissions have to be reported.

Because they are confidential, data on consumption and emissions in connection with perfluorodecalin are reported under CRF 2.H.

Hydrofluoroether emissions are reported on a voluntary basis, under "additional greenhouse gases".

Emission factors

The emission factors used have been obtained from opinions provided by experts; they are listed in Table 153 .

The EF_{use} for all medical and cosmetic applications is 100 %.

In agreement with the IPCC specifications (2006 IPCC Guidelines, p. 8.32), a 100 % emissions level for use of perfluorodecalin (EF_{use} = 1) is assumed. In a departure from the Guidelines, Germany applies a product lifetime of only one year in this area. The emission factor has thus been classified as "country-specific".

The IPCC Guidelines do not provide any instructions relative to the use of hydrofluoroethers as inhalation anaesthetics.

Activity data

The annual imports of $C_{10}F_{18}$ to Germany, for use in ophthamology and research, were disclosed by the manufacturer F2 Chemicals, UK, on a confidential basis.

The quantities of cosmetic products containing $C_{10}F_{18}$ that are imported to Germany were disclosed, on a confidential basis, by the trading enterprise P2 cosmetics, which sells the products in Germany.

The quantities of hydrofluoroethers that are used as inhalation anaesthetics were determined via surveys of industry experts (hospitals, manufacturers of anaesthesia equipment), and with the help of literature references, in the framework of a research project (cf. ÖKO-RECHERCHE 2013.

4.8.2.11 Uncertainties and time-series consistency (2.G.2)

In the case of sound-proof glazing, since 2006 data from the top-down survey of annual new consumption, carried out on the basis of commercial sales data, have been compared with data from the *Federal Statistical Office's* pertinent annual surveys. This procedure, which may be considered reliable and complete, has increased data reliability. Due to the wide range of influencing factors, the $EF_{production}$ cannot be measured reliably. Estimates resulting from a survey of ten industry experts, conducted in 1996 and 1999 (the experts represented window manufacturers, suppliers of filling devices and one scientific institute), indicate, virtually conclusively, that the mean filling loss ranges between 30 % and 40 %. A 1 % rate is considered realistic for ongoing gas losses.

With regard to athletic shoes, the filled-quantities breakdown, by Member States, is subject to considerable uncertainties, in spite of the good quality of the data for the EU.

In the case of medical applications, the data on the quantities of perfluorodecalin used are considered to be of good quality, since they were obtained directly from the manufacturer (F2 Chemicals Ltd, UK), and that manufacturer is the sole exporter of perfluorodecalin to Germany. The uncertainties relative to cosmetic products are larger, since Germany's market for cosmetics is extremely dynamic, with the result that no reliable statistics for this purpose are available.

4.8.2.12 Category-specific recalculations (2.G.2 all)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.8.2.13 Category-specific planned improvements (2.G.2 all)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.8.3 Use of N_2O (2.G.3)

CRF 3.D (N_2O)	Gas	Key category		1990 Total emissions (Gg) & percentage (%)		2012 Total emissions (Gg) & percentage (%)		Trend
Other product manufacture and use	**N_2O**	**-**	**T**	**1,924.6**	**(0.16%)**	**257.7**	**(0.03%)**	**-86.61%**

Gas	Method used	Source for the activity data	Emission factors used
N_2O	CS	AS/Q	CS

The category *Use of N_2O* is a key category for N_2O emissions in terms of trend (cf. Table 6). Because relevant emissions have fallen sharply since 1990 (about -85 %), and thus an extremely low emissions level has been attained, the Single National Entity has decided, as part of its resources prioritisation, not to apply the more stringent methods to this category that are required for key categories.

4.8.3.1 Category description (2.G.3)

The German nitrous oxide market is dominated by Air Liquide, Linde AG and Westfalen AG, all of which are leading producers as well as importers. No nitrous oxide emissions occur in nitrous oxide production and in filling of the gas into gas bottles. Emissions occur solely in use of the gas. Medical applications represent the most important N_2O-emissions source. Other emissions sources include use of laughing gas as a propellant in whipped-cream aerosol cans and use in the semiconductor industry. N_2O is also released, in small amounts, in blasting. Nitrous oxide emissions in anaesthesia, a predominant emissions source since 1990, have been decreasing sharply, due to increasing use of intravenously administered anaesthetics instead of nitrous oxide. This trend is expected to continue.

Medicine – anaesthesia

In medicine, nitrous oxide, a gas with analgesic properties, is used for anaesthetic purposes. In such applications, nitrous oxide is mixed with pure oxygen, to produce an active gas mixture consisting of 70 % nitrous oxide and 30 % oxygen. In modern anaesthesia, the effects of nitrous oxide are enhanced through addition of other anaesthetics. While medical use of N_2O is not prohibited, there is strong resistence – especially in the German medical sector – against widespread, general use of the substance. Medical use of laughing gas has thus been decreasing continuously since 1990.

Food industry – whipped-cream aerosol cans

In the food industry, nitrous oxide is used as an additive known as "E 942". Foods sold in pressurised containers are extracted from such containers with the help of propellants. As it exits such a container, a food takes on either a foamy or a creamy consistency, depending on what type of food it is. Examples of relevant foods with added N_2O include whipped cream (from spray cans), quark, and various desserts such as ready-to-eat puddings (DIE VERBRAUCHER INITIATIVE E.V, 2005; LINDE GAS GMBH, 2005).

Semiconductor manufacturing

A wide range of different chemicals and gases is used in semiconductor production. Argon, ultra-pure oxygen, hydrogen, ultra-pure helium and nitrogen account for the lion's share of the gases used. Special process gases, such as nitrous oxide (dinitrogen monoxide), ammonia and hexafluorethane, are used only in relatively small amounts, and the amounts involved have remained nearly constant over the past few years (AMD Saxony LLC&Co. KG, Dresden, Umweltbericht (environmental report) 2002/2003, page 16).

Explosives

Explosives are used in both military and industrial contexts. Civil and commercial explosives are used in mining, in construction in rocky terrain, in demolition, in geology and in fireworks.

Nitrous oxide emissions occur primarily in detonation of explosives that contain ammonium nitrate, such as ANFO (ammonium nitrate / fuel oil) and emulsion explosives. In general, commercial / civil explosives consist to some 60 to 80 % of ammonium nitrate (AN). By contrast, Andex, an ANFO explosive, contains up to 94 % ammonium nitrate.

In Germany, two companies produce explosives for civil use: Orica Mining (formerly Dynamit Nobel) and Westpreng GmbH (Wasag Chemie).

While no nitrous oxide emissions occur in manufacturing of explosives, nitrous oxide can form in thermal decomposition of explosives. The reason for this is that ammonium nitrate (AN) forms nitrous oxide (laughing gas) and water as it decomposes thermally.

Under careful warming to a temperature above the melting temperature, the reaction is as follows:

$$NH_4NO_3 \longrightarrow N_2O + 2H_2O$$

But in a fast, detonative reaction of an AN-containing explosive, the reaction occurs as follows:

$$NH_4NO_3 \longrightarrow 2H_2O + N_2 + 0{,}5O_2$$

This means that under high pressure and temperature AN primarily forms nitrogen, oxygen and water as it reacts. Only a small concentration of primarily formed N_2O remains intact in the detonation process. For example, detonation clouds of amatols[76], which contain some 80 % AN, have only 0.1 mole N_2O per mole of ammonium nitrate. From this figure, a theoretical maximum of about 68 g (this figure was provided by an explosives expert; the stoichiometric value would be 44 g/mole amatol (80%-AN)) per kilogramme AN can be calculated (ORELLAS, D.L., 1982; VOLK, F., 1997, page 74). According to experts, this AN-content figure can be used as a basis for assumptions regarding N_2O emissions for other explosives.

N_2O in automobile tuning

In automotive technology, nitrous oxide is used to improve combustion in gasoline / petrol engines, via so-called "laughing-gas injection". In the process, laughing gas is broken down into nitrogen and oxygen. The nitrogen cools the combustion process, and the oxygen increases combustion power. This "tuning" tactic can quickly increase engine performance. To date, one company in Germany offers such tuning measures. Research has shown that the equipment used for such tuning is designed to consume the input laughing gas completely, without producing significant emissions.

4.8.3.2 Methodological issues (2.G.3)

Anaesthesia

The 1990 figure for N_2O emissions from medical applications is based on an extrapolation of a statistical plant survey conducted in 1990 in the territory of the former GDR. At the time, it was ascertained that one plant for the production of N_2O for anaesthetic purposes had existed in the former GDR. Also at the time in question, the plant had not yet been operational for long (it was constructed in 1988). The annual production capacity was approximately 1,200 t. Research indicated that there were no exports or imports of this substance, and thus it was assumed that all of the substance was used for domestic consumption. Via the per-capita emissions calculated from this for the former GDR, and assuming identical conditions, N_2 emissions of 6,200 t were estimated, as a rough approximation, for Germany in 1990. The N_2O figure for 2001 was obtained via a written memorandum, dating from 2002, of the Industriegaseverband e.V. (IGV) industrial-gas association. That figure was tied to a range of 3,000 ~ 3,500 t/a. The mean value from that range (3,250 t/a) was then used for generation of an N_2O-emissions time series.

Since 2005, the Industriegaseverband (IGV) industrial-gas association has carried out surveys of N_2O sales for all applications in Germany. In addition, the IGV has made the data from those surveys available to the Federal Environment Agency for reporting purposes. In 2010, the IGV entered into a voluntary agreement, with the Federal Ministry of Economics and Technology (BMWi), regarding annual provision of N_2O-sales data for purposes of emissions reporting.

The gaps in the data relative to uses in anaesthesia are closed via interpolation and extrapolation.

The pertinent emission factor is 100%.

[76] Amatol x/y : military explosives – pourable mixtures, generally consisting of x % TNT and y % ammonium nitrate

Whipped-cream aerosol cans

Use of N_2O in aerosol cans for whipped cream, in Germany, has to be carefully differentiated. In Germany, there is one maker of aerosol cans for whipped cream. That maker also fills the cans in Germany. In emissions calculations, it is assumed, on the basis of the above-described research, that that company accounts for a share of about 3 % of the laughing-gas sales of the IGV industrial-gas association. Most of the companies who deal with such aerosol cans have them filled abroad and then import them into Germany. The relevant sales of such companies are thus not included in the data of the IGV industrial-gas association. The MIV dairy-industry association has reported to the Federal Environment Agency the results of a one-time survey that showed that 50.2 million units of whipped-cream aerosol cans were sold in 2008. At the same time, the MIV association reported that the units involved vary in size, and that it is not possible to break the figures down by can sizes. Internet research showed that pressurized cartridges for this area are sold in Germany: cartridges with 8g of N_2O, for 0.5l (whipped-cream) cans, and cartridges with 16g of N_2O, for 1.0l cans. Comparison calculations have shown that 8g of N_2O is a safe approximation, for purposes of calculation, for the amount of laughing gas contained per sold unit (whipped-cream aerosol can). That, in turn, leads to an input figure of 401.6 t N_2O for whipped-cream aerosol cans in 2008 in Germany. Since no pertinent data are available for the years prior to 2008, that value is assumed to be constant.

The emission factor for whipped-cream aerosol cans is assumed to be 100%.

Semiconductor manufacturing

On a one-time basis, the German Electrical and Electronic Manufacturers' Association (ZVEI) has provided information on quantities of laughing gas sold in the years 1990, 1995, 2000, 2001 and 2008. Values between those points are obtained via interpolation.

A wide range of different chemicals and gases is used in semiconductor production. Argon, ultra-pure oxygen, hydrogen, ultra-pure helium and nitrogen account for the lion's share of the gases used. Special process gases, such as nitrous oxide (dinitrogen monoxide) and ammonia, are used only in relatively small amounts, and the amounts involved have remained nearly constant over the past few years (AMD Saxony LLC&Co. KG, Dresden, Umweltbericht (environmental report) 2002/2003, page 16).

Explosives

In 2003, a total of 59 kt of explosives was produced in Germany. Of that figure, 13 kt were exported abroad, and 5.8 kt were imported into Germany[77]. Those figures, in turn, yield a figure of 51.8 kt for the amount of explosives used in Germany. Of that amount, ANFO accounts for a share of 60 %, emulsion explosives account for 25 % and dynamite explosives account for 15 %. ANFO explosives consist of 94 % ammonium nitrate and 6 % fuels. The corresponding relationship for emulsion explosives is 80 % to 20 %; for dynamite explosives, it is 50 % to 50 %.

At present, the quantities of nitrous oxide present in detonation clouds are not determined, while the pertinent quantities of NO and NO_2 are determined.

Normally, N_2O formation plays a significant role only in explosives that contain ammonium nitrate (AN). That said, no precise analyses of detonation clouds of ANFO explosives have

[77] Personal communication: Federal Office for Material Research and Testing (BAM).

been carried out. For this reason, it must be assumed that the N_2O concentrations formed upon detonation of ANFO are similar, with regard to AN content, to those formed upon detonation of amatols and ammonites[78], for which analyses have been carried out that support relevant estimates. The following result has been obtained: upon detonation, amatoles and ammonites form about 0.1 mole N_2O per mole of ammonium nitrate (AN).

According to the *Federal Office for Material Research and Testing* (BAM), levels of explosives use in Germany remained constant from 1990 to 2005.

The emission factor for use of explosives is 0.1036 kg N_2O/t explosives. That emission factor was determined, via measurement, by the BAM in February 2010. As a result, the emission factor has been corrected downward, considerably, with respect to the 2010 Submission.

For whipped-cream aerosol cans and the semiconductor industry, the pertinent emissions are reported in aggregation with confidential emissions data from N-dodecandiacid production (2.B.10).

4.8.3.3 Uncertainties and time-series consistency (2.G.3)

Since 2005, activity data for anaesthetic uses have been obtained from association information. For that reason, the uncertainty is estimated to be 20 %. The data on consumption for whipped-cream aerosol cans are subject to a very high level of uncertainty (75 %), since the relevant calculation is based on several assumptions and since a definite figure is available only for 2008. The uncertainty of the activity data for the semiconductor industry is estimated at 10 %, since the data have been obtained from facility operators themselves.

The uncertainty in the emission factors for anaesthesia and whipped-cream aerosol cans is set as 0 %, since at present it is assumed that N_2O undergoes no transformation in use, and that the gas thus escapes completely into the atmosphere following its use. The emission factor for use in semiconductor manufacturing is estimated to have an uncertainty of 15 %, since the data have been obtained from facility operators themselves. The emission factor for explosives is estimated to have an uncertainty of 5 %, since the emission factor has been determined via an official measurement.

With these results, the time series can be considered to show a normal type of distribution.

4.8.3.4 Category-specific QA/QC and verification (2.G.3)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

With regard to use in anaesthesia, a comparison with other countries shows that most other countries use an emission factor of 1.0, as Germany does. That factor is equivalent to the default value given in the IPCC GL 2006, Volume 3, p.8.36.

With regard to nitrous oxide emissions from use of explosives, no comparisons with other comparison or data sources are possible, since Germany is the only country that reports such emissions.

[78] Ammonite: Composition: 70-88 % ammonium nitrate, with 5-20 % nitroaromates, 1-6 % vegetable flour and, in some cases, 4 % nitroglycerine, aluminium powder and potassium perchlorate

The quantities of nitrous oxide used cannot be verified via other data sources, since no other data are available that would support such verification. A special survey was carried out in order to obtain the data for the present report.

4.8.3.5 Category-specific recalculations (2.G.3)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.8.3.6 Category-specific planned improvements (2.G.3)

No further improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.8.4 Other – ORC systems (2.G.4 ORC systems)

4.8.4.1 Category description (2.G.4 ORC systems)

Fluorinated greenhouse gases have been used in ORC systems in Germany since 2003. They are reported in category 2.G.4.

The Organic Rankine Cycle (ORC) is used for generating electricity from heat sources with temperatures and pressures that are too low for steam-powered generation. ORC systems are used especially in geothermal power generation and in harnessing of waste heat from combined heat and power (CHP) stations and biogas plants.

The working media used in the ORC cycle are certain organic substances, such as HFCs, PFCs, hydrocarbons and silicone oils, that evaporate at lower temperatures than water does. In ORC systems, such working media evaporate and drive turbines, just as steam drives turbines in conventional power stations. The largest fill quantities, far and away – up to 75 tonnes of fluorinated working media in each case – are used in geothermal applications. Considerably smaller fill quantities (0.2 to 0.6 tonnes) are used in systems that harness waste heat from biogas plants and in compact combined heat-and-power (CHP) generating systems.

In Germany, C_5F_{12} was first used as a working medium – in an ORC pilot system – in 2003. That system was decommissioned in 2010. HFC-134a was used for the first time in an ORC system in 2008. In 2010, HFC-245fa was used for the first time as a working medium. Beginning 2011, several systems were commissioned that operate with HFC-245fa and with the working medium "Solkatherm", which consists of HFC-365mfc (65 %) and a perfluorinated polyether (PFPE) with the trade name "Galden" (35 %).

4.8.4.2 Methodological issues (2.G.4 ORC systems)

Emissions from ORC systems occur during filling, operation and disposal.

Production emissions are determined via new domestic consumption – the activity data – and calculated pursuant to Equation 1.

Emissions from use are determined on the basis of final quantities (i.e. in systems) of working media – the activity data – and via multiplication by the EF_{use}, in keeping with Equation 2 .

Disposal emissions refer to new additions for the year that is x years (depends on product lifetime) prior to the current reporting year n. They are calculated pursuant to Equation Equation 3.

Apart from one exception, disposal emissions have not begun playing any role yet, since most systems are new. Large ORC systems in geothermal applications are expected to have a useful lifetime of 30 years, while smaller systems are expected to have lifetimes of 20 years.

The perfluorinated polyether "Galden" is reported under "additional greenhouse gases". In keeping with the recommendation in Paragraph 33 of the 2014 UNFCCC Reporting Guidelines, in addition to reporting on greenhouse gases as required, Germany is reporting on a number of emissions not subject to reporting obligations. For reasons of confidentiality, those emissions data have been combined with data on other emissions not subject to reporting obligations. They are reported in Chapter (CRF 2.H).

Emission factors

The emission factors used have been obtained from opinions provided by experts; they are listed in Table 153.

The filling loss is 2 %. It is country-specific, since ORC systems have not yet been covered by the IPCC Guidelines and thus no default factors are yet available.

The emissions from use are estimated to be 4 %. In this area as well, the IPCC Guidelines provide no specifications.

Under the current technological state of the art, the emission factor for disposal is 20 %. That value is also country-specific.

Activity data

ORC systems are a new area of application for fluorinated greenhouse gases, an area for which little data and technical information has been gathered to date. Almost all of the data used, therefore, are based on information provided by producers and operators of ORC systems. The data have been determined via discussions with experts (cf. ÖKO-RECHERCHE 2013).

4.8.4.3 Uncertainties and time-series consistency (2.G.4 ORC systems)

The uncertainties for the "ORC systems" sub- category have been systematically quantified.

The data on the quantities used are considered to be of good quality overall. Germany has only a small number (fewer than 10 companies) of manufacturers and sellers of ORC systems with florinated working media, and the country's market is relatively small. The data on the quantities of HFC-245fa and Solkatherm (HFC-365mfc and PFPE) that are used annually are of good quality, since the data come directly from the manufacturers of these working media (Honeywell und Solvay Solexis), and these companies are the only sellers who export to Germany.

The emission factors are subject to considerable uncertainties. Since sales of ORC systems in Germany began only a few years go, no pertient, solid empirical studies have been carried out to date. The values are based on estimates provided by operators of such systems.

4.8.4.4 Category-specific quality assurance / control and verification (2.G.4 ORC systems)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

4.8.4.5 Category-specific recalculations (2.G.4 ORC systems)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.8.4.6 Category-specific planned improvements (2.G.4 ORC systems)

No further improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.8.5 Other product manufacture and use: Other, charcoal use (2.G.4 Charcoal)

4.8.5.1 Category description (2.G.4 Charcoal)

In this category, CO_2, CH_4, N_2O and particulate emissions from use of charcoal are reported. Emissions of particulates, precursor substances and heavy metals from use of cigarettes and fireworks are reported.

Only small quantities of charcoal are produced in Germany – by one major charcoal-factory operator and in a number of demonstration charcoal kilns. The pertinent quantities are determined by the Federal Statistical Office (STBA) and are subject to confidentiality requirements. Production of charcoal is reported under 1.B.1.b.

Use of charcoal increased steadily in the years 1990 through 2013. The great majority of the charcoal used is imported.

4.8.5.2 Methodological issues (2.G.4 Charcoal)

The calculation model is based on the assumption that all calculation method is consumed within a year of its purchase and is burned completely.

The CO_2, CH_4 and N_2O emissions are calculated via a Tier 1 method.

Activity data

The data on charcoal production, and on the imported and exported quantities, for the years 1996 through 2013, were obtained from the Federal Statistical Office (STATISTISCHES BUNDESAMT, Fachserie 4, Reihe 3.1, Produzierendes Gewerbe, Produktion im Produzierenden Gewerbe sowie der Außenhandelsstatistik ("manufacturing industry; production in the manufacturing industry and foreign-trade statistics").

The quantities consumed are calculated in keeping with the formula Production + Imports – Exports.

For the years 1990 through 1995, the quantities consumed are calculated from the per-capita consumption, which has been derived from the data for the years 1996 through 2013. In the process, it is assumed that consumption also grew linearly in those (earlier) years.

Emission factors

Since import and export data are published, no exact emission factors for CO_2, CH_4 and N_2O may be given, for reasons of confidentiality. It may be disclosed, however, that the relevant emission factors are of the same order of magnitude as the factors that can be derived from the 2006 IPCC Guidelines.

The calculation model is based on the assumption that all calculation method is consumed within a year of its purchase and is burned completely.

The CO_2, CH_4 and N_2O emissions are calculated via a Tier 1 method.

4.8.5.3 Uncertainties and time-series consistency (2.G.4 Charcoal)

A Tier 1 method, with emission factors similar to those provided by the 2006 IPCC Guidelines, has been used, and thus that source's relevant uncertainties for the activity data and emission factors apply (2006 IPCC Guidelines, Volume 3, Chapter 5).

4.8.5.4 Category-specific quality assurance / control and verification (2.G.4 Charcoal)

General quality control, and quality assurance in conformance with the requirements of the QSE manual and its associated applicable documents, have been carried out. Due to resource limitations, the Single National Entity was unable to carry out additional quality control and quality assurance.

4.8.5.5 Category-specific recalculations (2.G.4 Charcoal)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.8.5.6 Category-specific planned improvements (2.G.4 Charcoal)

No further improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.9 Other production (2.H)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/-	2.H Other	0	HFC	421.8	(0.03%)	127.6	(0.01%)	-69.8%

The category *Other production* is not a key category.

In the CSE, process-related emissions from production of particle board and from pulp production are reported under 2.H.1 Pulp and paper.

Process-related emissions from production of alcoholic beverages, and from production of bread and other foods, are listed under 2.H.2 Food and drink.

Confidential data on emissions of fluorinated greenhouse gases are reported under 2.H.3. Data on F gases subject to voluntary reporting are reported in that section as well, in aggregated form.

4.9.1 Other production: Pulp and paper (2.H.1)

4.9.1.1 Category description (2.H.1)

Gas	Method used	Source for the activity data	Emission factors used
NO_X, CO			CS
NMVOC, SO_2			D

The category *Other production – pulp and paper* is not a source of greenhouse-gas emissions and is thus not a key category.

All emissions of climate-relevant gases from the pulp and paper industry, and from particle-board production, in Germany result from combustion of fuels; for this reason, they are reported in Chapter 3.2 as energy-related emissions. The pulp and paper industry does not produce any process-related emissions of climate-relevant gases within the meaning of the *IPCC Good Practice Guidance* (2000).

Two of the six pulping plants in Germany carry out sulphate-process **pulp production** via caustification. For these plants, fuel-related CO_2 emissions in lime ovens are already taken into account, as energy-related emissions, via the pertinent fuel statistics. The remaining four plants use the sulphite process.

No attempt was made to take account of country-specific CO emission factors in energy-related emissions from pulp production, since that would have required conversion of product-based emission factors into fuel-based emission factors. Such conversion is an extremely involved process. Compared to the relevant CO emissions from paper mills, the CO emissions from the six pulping plants are of insignificant quantities.

The sulphate and sulphite pulp-production processes can both be a source of SO_2 emissions. In sulphate pulp production, NO_X, CO and NMVOC emissions are also released from recovery boilers, lime ovens, bark boilers and auxiliary boilers.

Particle board is produced from wood chips, with added binders, in a process that applies heat and pressure. The main source of NMVOC emissions in such production are the wood chips used, which release NMVOC during drying via heating. NMVOC can also be emitted from wood and binders during the pressing process.

Particle board is produced in a total of 16 plants in Germany. Some 6,000 employees work in particle-board plants nation-wide. The particle-board industry tends to be dominated by larger companies.

4.9.1.2 Methodological issues (2.H.1)

The **pulp and paper industry** produces no process-related emissions of climate-relevant gases within the meaning of the *IPCC Good Practice Guidance* (IPCC, 2000). For indirect greenhouse gases, the IPCC-Guidelines emission factors listed in Table 156 were used until the reported year 2004.

Table 156: IPCC default emission factors for SO_2, NO_x, CO and NMVOC from pulp production

	NO_X	CO	NMVOC	SO_2
		[kg / t ADt*]		
Sulphate pulp	1.5	5.6	3.7	7
Sulphite pulp				30

* ADt = Air-dried tonne

As of reported year 2005, plant operators have provided updated emission factors.

Table 157: Real emission factors, for German plants, from pulp production. (German contribution to revision of the BAT reference (BREF) document for the pulp and paper industry, 2007)

	NO_X	CO	NMVOC	SO_2
		[kg / t ADt*]		
Sulphate pulp	1.75	0.16	3.7	0.05
Sulphite pulp	2			2

In 2013 the following quantities were produced, in a total of 164 plants:

Table 158: Pulp and paper production, produced quantities

Product	Quantities produced in 2013	
Production of paper, cardboard and carton (PCC):	22.39	million t
Raw-material production:		
Paper pulp	1,594,896	t
of this, sulphite pulp	*616,639*	*t*
of this, sulphate pulp	*978,257*	*t*
Wood pulp	1,043,000	t
Recycled paper	13,516,000	t
Quantity of recycled paper used for this purpose	(16,168,000	t)

Source: Verband Deutscher Papierfabriken, Leistungsbericht 2010 (VDP, various years)

These figures, which the German Pulp and Paper Association (VDP) collects annually and publishes in a production report, are available back to the reference year, 1990.

Particle board

Emission factors

The emission factors have been determined on the basis of experts' assessments.

Activity data

The activity data were obtained from national statistics (STATISTISCHES BUNDESAMT (FEDERAL STATISTICAL OFFICE): Fachserie 4, Reihe 3.1).

Table 159: Updated activity data for the particle-board industry

Year	2008	2009	2010	2011	2012	2013
Activity data for the particle-board industry [in t]	5,300,000	4,575,000	4,561,000	4,488,000	4,429,000	4,488,000

Source: Federal Statistical Office, Fachserie 4, Reihe 3.1.4

4.9.1.3 Uncertainties and time-series consistency (2.H.1)

Pulp and paper

Until reported year 2004, the IPCC default values (IPCC, 1996b) were used for emissions calculation. As of reported year 2005, updated, Germany-specific emission factors were entered into the CSE emissions database, following consultation with German plant operators. Such updating was required because German sulphate pulp plants had undertaken considerable modernisation measures, in the previous five years, that had led to sharp emissions reductions. The updating was completed as of 2005. In sulphite pulp plants, continual improvements led to considerable SO_2-emissions reductions with respect to corresponding emissions levels in 1990.

The uncertainties in the activity data are estimated at 5-10 %. The uncertainties in the emission factors are estimated at 20 %.

Particle board

The uncertainties in the activity data for the particle-board industry are ±5 % (expert assessment).

4.9.1.4 Category-specific QA/QC and verification (2.H.1)

Due to resources limitations, and to the area's minimal relevance, no QC/QA is carried out for reporting relative to precursors.

4.9.1.5 Category-specific recalculations (2.H.1)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.9.1.6 Category-specific planned improvements (2.H.1)

Since plant operators have confirmed the emission factors from the international guidelines, no further inventory improvements for this category are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.9.2 Other production: Food and drink (2.H.2)

4.9.2.1 Category description (2.H.2)

Gas	Method used	Source for the activity data	Emission factors used
CO_2	NA	NA	NA
NMVOC	CS	NS	CS/D

The category *Other production – food and drink* is not a source of greenhouse-gas emissions and is thus not a key category.

The food and beverage industry's emissions of direct climate gases in Germany result from fuel combustion; for this reason, they are reported under CRF 1.A.2. The food and beverage industry's important process-related emissions include non-methane volatile organic compounds (NMVOC) (IPCC 1996c: p. 2.41). Carbon dioxide emissions from food inputs that occur during certain production processes are not reported in CRF 2.D.2., since they result from use of biological carbon and do not contribute to net CO_2 emissions. Solvent emissions related to production of margarine and vegetable oils are reported in category 3.D. Animal fats are thus included in the category "Margarine and solid and hardened fats". CO_2 used in sugar production, which is obtained from burning of limestone, is bound during the production process. Therefore, that process is not emissions-relevant (cf. UFOPLAN research project FKZ 205 41 217/02); UBA, 2006).

Emissions of the food and drink industry are reported, in summary form, in the inventory in "Table2(I)s2" of the sectoral report for industrial processes. In the table "Background data of the sectoral report for industrial processes" ("Hintergrunddaten des sektoralen Reports für Industrielle Prozesse"), "Table2(I).A-G", the IEF is listed as NE, since the pertinent CO_2 emissions are reported under CRF 1.A.2.

Pursuant to the IPCC, emissions reporting for the food and drink category covers the following products:

Alcoholic beverages

- Wine
- Beer
- Spirits

Bread and other foods

- Meat, fish and poultry
- Sugar
- Margarine and solid and hardened fats
- Cake, cookies and breakfast cereals
- Bread
- Animal feedstuffs
- Coffee roasting

Default emission factors for NMVOC emissions relative to these products are listed (IPCC, 1996c: p. 2.41f).

4.9.2.2 Methodological issues (2.H.2)

For emissions calculations, national emission factors were used where available. Otherwise, the emission factors recommended by IPCC and CORINAIR were used. The basis for selection of emission factors consists of the research report "Emissions from the food industry" ("Emissionen aus der Nahrungsmittelindustrie") (FKZ 206 42 101/01; IER, 2008). The procedure is in keeping with that described in the NIR 2013.

For category 2.H.2, a total of 14.1 Gg of NMVOC emissions result for 2013. Of those, 4 Gg NMVOC are from sugar production and 3.3 Gg NMVOC are from production of spirits.

4.9.2.3 Uncertainties and time-series consistency (2.H.2)

The uncertainties in the activity data are estimated to amount to 5-20 %. Further information about the relevant uncertainties is provided in the NIR 2013.

4.9.2.4 Category-specific QA/QC and verification (2.H.2)

Due to resources limitations, and to the area's minimal relevance, no QC/QA is carried out for reporting relative to precursors.

Other countries' reports contain very little information about 2.H.2, and thus no comparisons are possible at present. No comparison with ETS data is possible, since no emissions subject to emissions trading occur in 2.H.2.

4.9.2.5 Category-specific recalculations (2.H.2)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

4.9.2.6 Category-specific planned improvements (2.H.2)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

4.9.3 Other (2.H.3)

Gas	Method used	Source for the activity data	Emission factors used
HFC, PFC, SF_6		cf. Table 152	

Emissions of SF_6 from use in *Athletic shoes* (2.G.2.d. Adiabatic properties – Athletic shoes), use in *AWACS maintenance* (2.G.2.a Military uses) and use in *welding* (2.G.2.e Other – Welding) are reported 2.H.3, for reasons of confidentiality.

HFC emissions from use of the solvents HFC-43-10mee, HFC-245fa, HFC-365mfc and C_6F_{14} (2.F.5) are also reported under 2.H.3.

PFC emissions from use in athletic shoes (2.G.2.d Adiabatic properties – Athletic shoes), and the use of perfluorodecalin in *medical and cosmetic applications* (2.G.2.e Other – Medical and cosmetic applications), are also reported under 2.H.3.

In keeping with a recommendation of the Expert Review Team, it is noted that all information relative to the emissions reported under 2.H.3 – including category description, methodological issues, uncertainties & time-series consistency, category-specific recalculations & verification and planned improvements – is presented in the pertinent category chapters.

No other sources of relevant greenhouse-gas emissions are known.

In addition to reporting on greenhouse gases subject to reporting obligations, Germany has decided to report on the greenhouses gases listed in the following table, for the applications listed in the table, that are not subject to reporting obligations. Since a number of these applications are confidential, the data are presented only in aggregate form.

Table 160: Aggregated data on emissions (aggregated to protect confidentiality) of the additional greenhouse gases, which are not subject to reporting obligations, HCFE-235da2, HFC-1234yf, HFC-1234ze, HFE-236ea2, HFE-347mmz1 and PFPMIE, from the following applications: inhalation anaesthetic, automobile air-conditioning systems, stationary air-conditioning systems, XPS insulation and ORC systems

Total of HCFE-235da2, HFC-1234yf, HFC-1234ze, HFE-236ea2, HFE-347mmz1 and PFPMIE from the following applications: inhalation anaesthetic, automobile air-conditioning systems, stationary air-conditioning systems, XPS insulation and ORC systems	
Year	**Emissions, in t CO_2 equivalent**
1990	9,275.0
1991	11,235.0
1992	13,300.0
1993	15,470.0
1994	17,745.0
1995	20,125.0
1996	24,437.3
1997	28,435.2
1998	32,617.5
1999	36,992.4
2000	41,496.0
2001	44,892.6
2002	48,361.3
2003	52,036.0
2004	55,662.3
2005	59,494.6
2006	65,556.4
2007	67,445.5
2008	69,406.7
2009	71,367.9
2010	73,280.7
2011	75,289.4
2012	76,952.5
2013	78,415.4

5 AGRICULTURE (CRF SECTOR 3)

5.1 Overview (CRF Sector 3)

5.1.1 Categories and total emissions, 1990 - 2013

In category 3, "Agriculture", Germany reports on emissions from enteric fermentation (3.A), from manure management (including manure digestion and storage of manure digestion residues) (3.B) and from agricultural soils (3.D). In addition, it reports on CO_2 emissions from liming (3.G) and urea application (3.H). The present 2015 NIR also reports, for the first time, on emissions occurring in connection with digestion of energy crops (3.J: Emissions from digestion of energy crops and storage of the respective digestates; 3.D: Emissions from application of digestion residues).

Emissions from rice cultivation (3.C) do not occur in Germany, while clearance of land by prescribed burning (3.E) is not practiced in Germany (NO). Field burning of agricultural residues (3.F) is prohibited in Germany, although it must be noted that some exemptions are permitted, and these do not lend themselves to surveys. Such exceptions are considered to be irrelevant (NO). The CO_2 emissions to be reported in sector 3.I (other lime fertilisers) are included in 3.G.

For the present 2015 NIR, Figure 47 provides an overview of the development of greenhouse-gas emissions, since 1990, in the areas 3.A, 3.B, 3.D, 3.G and 3.H. The pertinent data have been calculated with the GAS-EM inventory model (cf. Chapter 5.1.2).

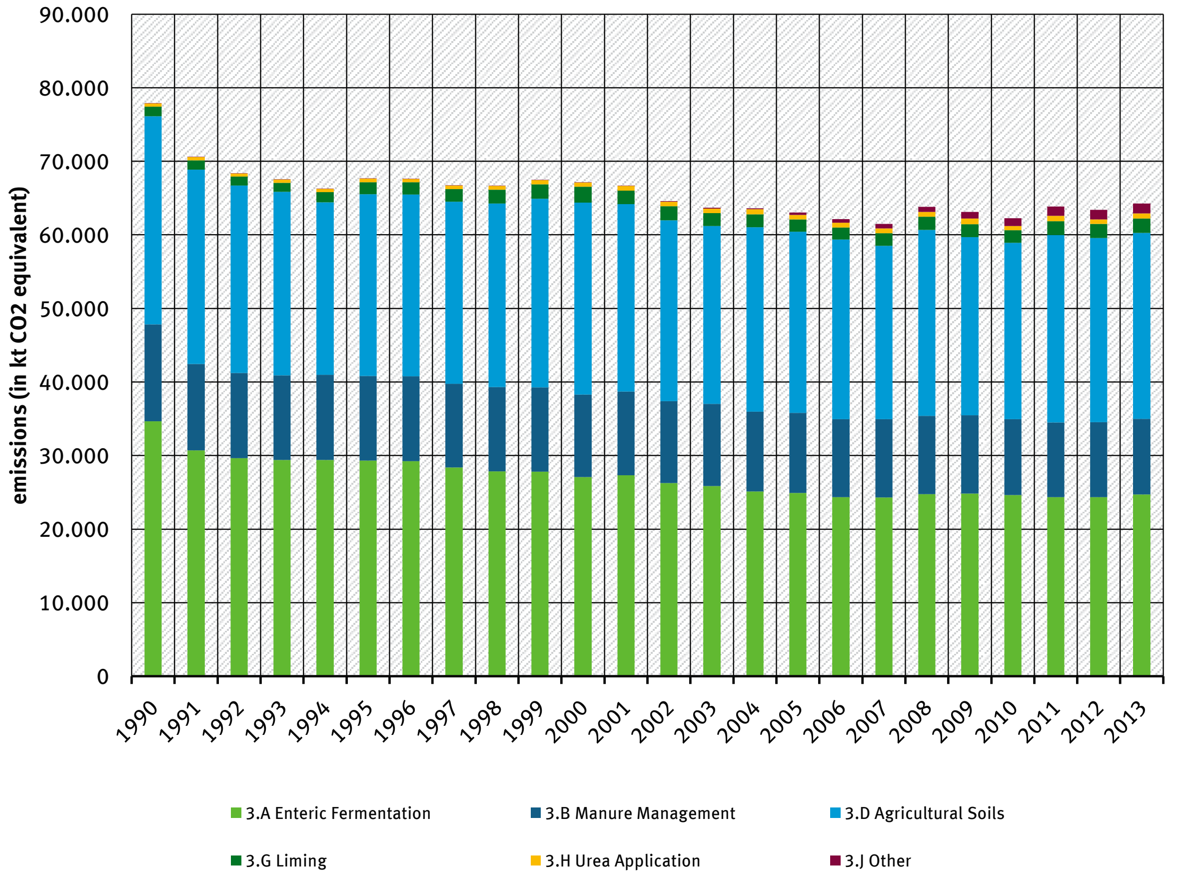

Figure 47: Overview of greenhouse-gas emissions in CRF Sector 3

5.1.2 The GAS-EM emissions-inventory model

5.1.2.1 Guidelines applied, and detailed report

The GAS-EM emissions-inventory model is based primarily on the relevant sets of guidelines (greenhouse gases: IPCC, 2000; IPCC 2006; pollutants, especially NH_3: EMEP, 2007; EMEP, 2009; EMEP, 2013). Previously, the calculations carried out in this area were based on the methods presented in IPCC (1996b). For the present 2015 NIR, all calculations have been converted to the methods described in IPCC (2006). The 2015 NIR reports, for the first time, on emissions from digestion of energy crops, emissions for which the aforementioned guidelines present no calculation methods.

Over the past few years, many of the methods described in the guidelines have been refined for purposes of the GAS-EM model. And a national method have been developed for calculation of emissions from digestion of energy crops. A comprehensive description of the GAS-EM inventory model, including documentation of additional sources, is presented in the pertinent detailed report (RÖSEMANN et al., 2015)[79]. The following chapters summarise the detailed report with regard to the aims for the 2015 NIR.

[79] An electronic version of the detailed report is available from: dieter.haenel@ti.bund.de claus.roesemann@ti.bund.de.

5.1.2.2 Basic structure of the GAS-EM emissions-inventory model

Feed intake serves as the basis for emissions calculations in the animal husbandry sector. It is calculated as a function of basic and yield-related energy requirements, as Figure 48 shows with the example of dairy cattle. That approach provides the CH_4 emissions from enteric fermentation (3.A), as well as the carbon and nitrogen excretions data needed to calculate emissions from management of manure and digestion residues (3.B). The latter, in turn, enter into calculations of nitrogen discharges into agricultural soils (3.D).

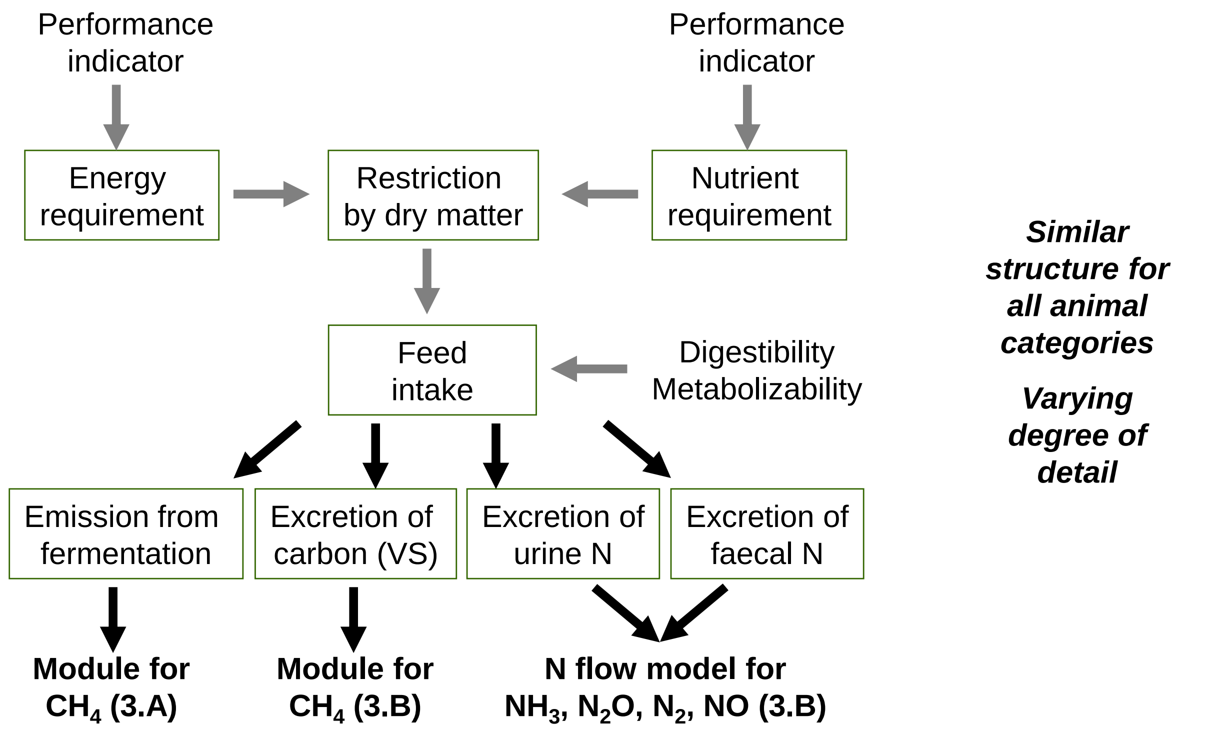

Figure 48: Logical structure behind national methods for calculating emissions from animal husbandry, illustrated with the example of dairy cows. ("Yield indicator" stands for the sum of basic and yield-related requirements.)

Figure 49 shows how the GAS-EM model, for purposes of calculations in categories 3.A and 3.B, first differentiates between animal categories and sub-categories and then further subdivides those categories into housing systems, storage systems and procedures for application of manure and digestion residues. CH_4 emissions are calculated separately for each animal sub-category in 3.A and 3.B. For categories 3.B and 3.D, N_2O emissions are calculated on the basis of an N-flow concept (cf. Chapter 5.1.2.4). In categories 3.G-I, CO_2 emissions are calculated for liming and urea application. In line with the IPCC's guidelines, these calculations also include liming of forests. Emissions from digestion of energy crops are calculated in two separate sections: Emissions from digesters and storage of digestion residues, in 3.J; and emissions from soils, as a result of application of digestion residues, in 3.D.

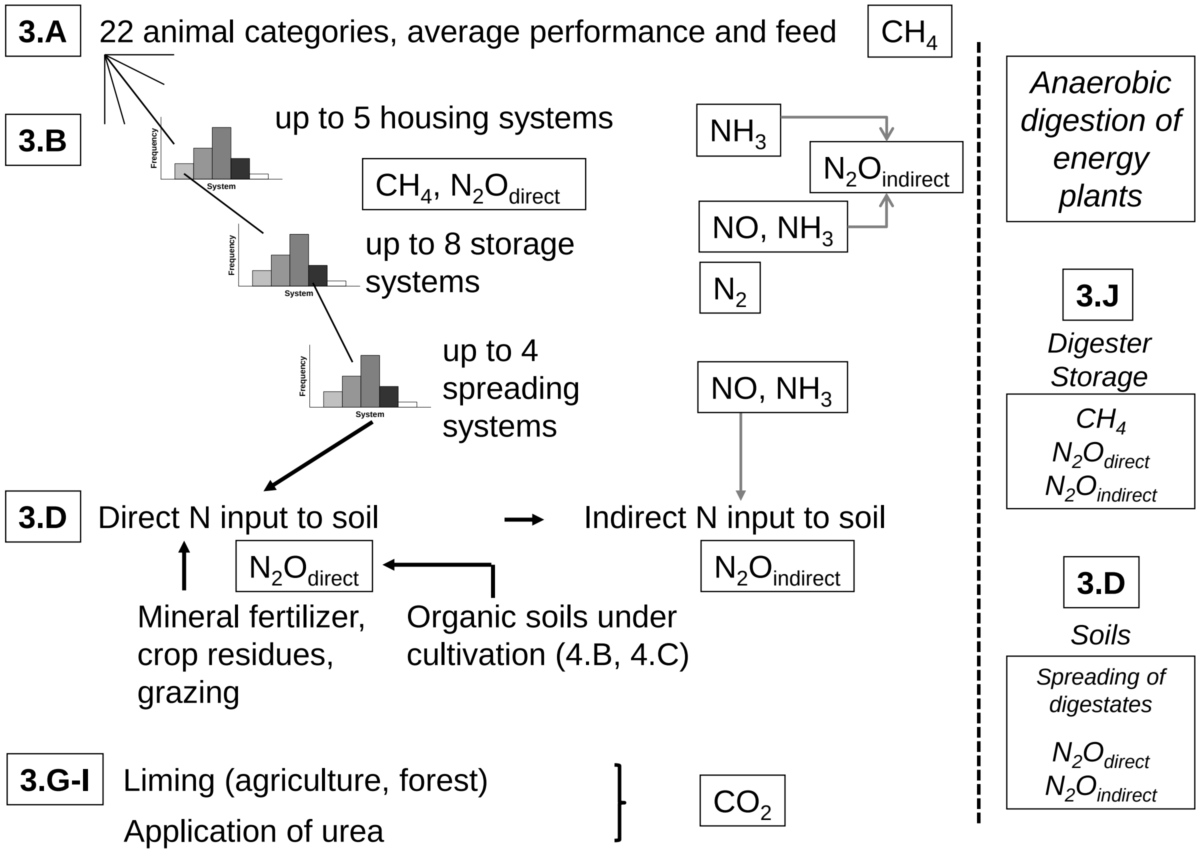

Figure 49: Concept and thematic content behind the GAS-EM model

5.1.2.3 Treatment of CH_4 within the emissions inventory

The GAS-EM inventory model is used to calculate CH_4 emissions from enteric fermentation and VS excretions of agricultural livestock (cf. Chapters 5.1.7 and 5.3.2), taking account of slurry-based and straw-based systems and their typical forms of storage. Anaerobic digestion of manure and energy crops, in biogas plants, is included in the calculations (cf. Chapters 5.1.3.6.5 and 5.1.4).

5.1.2.4 The nitrogen-flow concept (3.B, 3.D)

With the GAS-EM model, N-species emissions are calculated on the basis of the N-flow concept (DÄMMGEN & HUTCHINGS, 2005, RÖSEMANN et al., 2015).

To make it possible to apply the concept, the N amounts excreted in animal husbandry have to be determined. For dairy cattle, heifers, male beef cattle, swine, laying hens, pullets, broilers, ducks and turkeys, males and hens, N excretions are calculated as the difference between the amount of N taken in with feed and basic and yield-based N requirements (animal weight, weight gain, annual milk production or egg production (i.e. numbers of eggs) and, if relevant, numbers of young). The N intake with feed is determined on the basis of animal energy requirements and the energy and N content of the feed. For other animals, N-excretion data are taken from the pertinent German technical literature (cf. in this regard RÖSEMANN et al., 2015).

In the case of N excretions, a distinction is made between the two fractions "organic N" and "N readily converted into NH_3" (TAN – "total ammoniacal nitrogen"). TAN is present in the urine of mammals; in the GAS-EM model, in each case TAN is considered to be equivalent to the N content of urine. Poultry excrete "UAN" (uric acid nitrogen); in the inventory, UAN is treated as TAN. As a result of the manner in which the relevant emission factors are defined, NH_3 emissions are calculated primarily in proportion to the available TAN quantity, while N_2O emissions, NO emissions and N_2 emissions are calculated in proportion to the available N quantity. For this reason, the calculations take account of two parallel N pools. These are (1) the entire N quantity available at the relevant stage being considered, i.e. the sum of organic N and TAN, and (2) TAN by itself.

The N excretions determined for a given animal category are divided into stable emissions and pasture emissions. This division is made in accordance with the percentages of time the relevant animals spend in the stable and in pasture.

In the case of solid-manure systems, N inputs from bedding material are also taken into account, along with N excretions.

For each animal category, the amounts of N occurring in housing systems are divided in accordance with the relative shares of the animal-housing systems commonly used in Germany. N losses via NH_3 emissions are subtracted from the TAN pool and from the total N pool. The remaining N and TAN amounts for all stables are combined separately, for slurry-based systems and then for straw-based systems, and are transferred into the correspondent storage systems.

The N removed via air scrubbing systems is treated as TAN, as if it were directly applied with manure (see below).

The total N and TAN amounts (for solid-manure systems, including the N inputs from bedding) accruing to the storage systems are divided, separately for the categories solid manure and slurry, among the different storage systems commonly used in Germany, in keeping with the applicable percentage shares. Anaerobic digestion of manure in biogas plants is included in the calculations (cf. Chapter 5.1.3.6.5). From storage, NH_3 emissions from the TAN pool and the total N pool occur. The N losses occurring via emissions of N_2O, NO and N_2 are calculated as a total, for housing systems and for storage systems, and then subtracted from the total N pool. At the same time, these N losses are subtracted from the TAN pool, in a manner in keeping with the ratio of the TAN quantity to the total-N quantity. The remaining N / TAN quantities are applied to the field, with the N removed via air scrubbing systems being added to the TAN pool.

The amount of N applied is divided among the different application techniques commonly used in Germany, taking account of the different durations of manure incorporation commonly observed. This is carried out in accordance with the different application techniques' relative proportions of the total amount of manure applied, differentiated by animal category and by the categories of solid manure and liquid manure. The N losses occurring during application, via NH_3 emissions, are deducted from the TAN pool and the total N pool. The then remaining total-N quantity yields the N quantity available in the soil that is used for calculation of N_2O emissions from leaching and surface runoff. On the other hand, the N_2O emissions released from agricultural soils as a result of manure application are calculated in proportion to the N quantity applied.

The total-N quantity excreted during grazing yields the N quantity available in the soil that is used for calculation of N_2O emissions from grazing.

The N flows that occur in connection with digestion of energy crops, and with storage and application of the resulting digestion residues, are treated separately from the N flows for animal husbandry. The former are calculated on the basis of the N quantity in the digested energy crops (cf. Chapter 5.1.4.2), via a procedure analogous to that described above for animal N excretions.

5.1.3 Characterisation of animal husbandry

5.1.3.1 Animal categories (3.A, 3.B)

For calculation of emissions from animal husbandry in German agriculture, animal stocks are divided into sub-categories, to permit description of sub-stocks that are homogeneous with regard to yield and to housing systems. Table 161 compares the animal categories to be reported on in the in CRF tables with the animal categories used in the German inventory.

As of the present 2015 NIR, the CRF categories "mules and asses" and "buffalo" are reported as "IE". The numbers of animals previously reported in these categories are included in the numbers reported in the categories "horses" and "other cattle" (cf. Chapter 5.1.3.2.2).

The categories deer, rabbits, ostriches and fur-bearing animals (IPCC, 2006) are not reported, because their contribution to the total emissions is less than 0.05 % of the overall inventory or 500 kt CO_2 equivalents (pursuant to FCCC/SBSTA/2013/L.29/Add.1), and since it cannot be assured that annual inventories of such emissions (pursuant to FCCC/SBSTA/2013/L.29/Add.1, para 37) will be carried out. In Chapter 19.3.1, the relevant emissions contribution to the overall inventory is derived and described on a one-time basis. A compilation of all sources for which the entry "NE" is retained is presented in Annex 5 in Chapter 21.

Table 161: CRF animal categories, and the subdivisions used for purposes of German emissions reporting (3.A, 3.B)

CRF animal categories		Animal categories in the German inventory
1	Dairy cattle	"Dairy cows" [a]
	Other cattle	"Calves" (to 4 months) [a] Young female cattle older than 4 months ("heifers") Young male cattle older than 4 months ("male beef cattle") "Suckler cows" [a] "Male cattle older than 2 years"
2	Sheep	"Mature sheep" "Lambs"
3	Swine	"Sows" (incl. suckling piglets to 8 kg) "Weaners" "Fattening pigs" "Boars"

CRF animal categories		Animal categories in the German inventory
4	Buffalo	--- [a]
	Camels	--- [b]
	deer	--- [c]
	Goats	"Goats"
	Horses	"Heavy horses" [d] "Light horses and ponies" [d]
	Mules and asses	--- [d]
	Poultry	"Laying hens" "Broilers" "Pullets" "Geese" "Ducks" "Turkeys, males" "Turkeys, females"
	Rabbits	--- [c]
	Reindeer	--- [b]
	Ostriches	--- [c]
	Fur-bearing animals	--- [c]

[a] In the years through 2012, the German inventory included buffalo with suckler cows; as of 2013, the official animal-population figures that it presents for the categories "other cattle" and "dairy cows" include buffalo.The buffalo data cannot be separated out from those figures.

[b] These animals do not occur in Germany.

[c] These animals are not reported on, since their emissions contribution is insignificant.

[a] In the years through 2009, the German inventory included mules and asses with light horses and ponies; as of 2010, the official animal-population figures that it presents for horses include mules and asses. The data for those animals cannot be separated out from the horse figures.

5.1.3.2 Animal place data (3.A, 3.B)

The terms "animal place" and "place" (as units: pl) as used in the German inventory are in keeping with the definition of "average annual population" (AAP) in EMEP(2013), p. 13, and IPCC(2006)-10.8, equation 10.1. The term refers to an average animal place that is continuously occupied for production purposes. This definition of animal place is consistent with the assumption, used in the German inventory, that the numbers of animals determined by official statistics, as of a specific reference date (cf. Chapter 5.1.3.2.1), are constant throughout the year.

In the following, "numbers of animals" and "animal population" / "animal-population figures" are used interchangeably with "animal places".

5.1.3.2.1 Surveys of the Federal and Länder statistical offices

The Federal Statistical Office and the statistical offices of the Länder (federal states) carry out agricultural-structure surveys[80] that, in addition to collecting other data, carry out censuses of cattle, swine, sheep, horses (as of 2010: equids) and poultry. In the periods 1990 – 1996 and 1999 – 2007, such agricultural structural surveys were carried out every other year. In 2010, they were then carried out in the framework of the 2010 agricultural census (Landwirtschaftszählung 2010 – LZ 2010)[81], a more extensive census. Thereafter, they were not carried out again until 2013. The 1990, 1992, 1994 and 1996 surveys were each carried

[80] https://www.destatis.de/DE/Meta/AbisZ/Agrarstrukturerhebung.html

[81] https://www.destatis.de/DE/ZahlenFakten/Wirtschaftsbereiche/LandForstwirtschaft/Landwirtschaftszaehlung2010/Ergebnisse.html

out on 3 December. Surveys during the years 1999 – 2007 were referenced to 3 May, while the 2010 and 2013 surveys were referenced to 1 March.

In addition to agricultural-structure surveys, annual livestock censuses are carried out (STATISTISCHES BUNDESAMT, Fachserie 3, Reihe 4.1). Through 1998, such surveys were carried out semiannually for cattle and sheep (June, December), every four months for swine (April, August, December), and every two years, in even-numbered years (in December), for all animal species, i.e. also for horses and poultry. In each case, the reference date was the third calendar day of the pertinent month. Since 1999, the livestock census has been carried out twice yearly, and referenced to 3 May and 3 November, for cattle and swine; for sheep, it has been carried out once yearly, referenced to 3 May (as of 2011, to 3 November).

Census data from official surveys are thus available for cattle, swine and sheep for all years since 1990. In the inventories through 1998, the December data were used (for sheep, the June data). Thereafter, through 2010, the May data were used. As of 2011, by agreement with the Federal Statistical Office, the November reference date is to be used (EU Regulation No 1165/2008, Article 4). These figures are in keeping with the figures the Federal Statistical Office has provided to EUROSTAT. The change in the reference date, to 3 November, does not significantly affect the population figures in the case of cattle and swine. Among the figures for sheep, livestock-population figures had to be corrected; cf. Chapter 5.1.3.2.2.

For horses / equids, and for poultry, population figures are available only at intervals of two to three years, from agricultural-structure surveys (reference dates: through 1998, 3 December; 1999 – 2007, 3 May; 2010 and 2013, 1 March). By agreement with the Federal Statistical Office, the population figures have not been adjusted to take account for the variations in reference dates.

Chapter 5.1.3.2.2 discusses the population figures for the other animals, as well as special aspects related to useof official census data for cattle, swine and sheep.

5.1.3.2.2 Special aspects of animal-place figures in the inventory

Since 2008, cattle-population figures have been taken from the HIT database (Herkunftssicherungs- und Informationssystem für Tiere ("origin-tracing and information system for animals"; http://www.hi-tier.de) of the Bavarian State Ministry for Food, Agriculture and Forestry (Bayerische Staatsministeriums für Ernährung, Landwirtschaft und Forsten – StMELF), in which all cattle are individually registered. Via the new survey method, systematically higher population figures result for years as of 2008 than result for earlier years in which not all animals were counted, due to the survey thresholds applied. A comparison carried out by the Federal Statistical Office for 2007 reveals that the population figures for cattle shown in HIT are 2.9 % higher than those resulting via the conventional survey method (for dairy cattle alone, the population figures are 2.8 % higher). The Federal Statistical Office reports that the cattle time series for the period prior to 2008 will not be adjusted in this regard. As a result, emissions from keeping of cattle are slightly underestimated for the years 1990 to 2007. In the interest of obtaining maximally homogeneous animal categories, some of the cattle categories used in official surveys have been modified for purposes of the inventory. For the 2015 NIR, the final age for calves, and the starting age for heifers and male beef cattle, have both been raised from two months to four months; cf. RÖSEMANN et al., 2015. The transformation leads to higher numbers of calves and to lower numbers of heifers and male beef cattle, but it has no effect on the total number of cattle.

As of the time-series year 2013, the cattle population data provided by the Federal Statistical Office also include bison and buffalo. The buffalo numbers cannot be extracted from cattle data. As a result, as of the time-series year 2013 the buffalo emissions are included in the cattle emissions. Consequently, as of the 2015 submission buffalo are no longer treated as a separate category in the inventory (included elsewhere, IE). The emissions produced by buffalo in the time-series years 1990 through 2012 are taken into account in the inventory by adding the buffalo populations to the numbers of suckler cows. On the other hand, the Federal Statistical Office has not published any figures for buffalo. For this reason, figures of the Deutscher Büffelverband (German buffalo association) have been used for the period as of 2000. In keeping with a recommendation in the final report for the "Initial Review under the Kyoto Protocol and Annual 2006 Review under the Convention", for the years prior to 2000 the time series for the buffalo population at the national level was completed via linear extrapolation. For the years 1990 through 1995, mathematically negative population figures result; they are replaced with zeros.

For swine as well, several of the categories used in official surveys have been modified with a view to obtaining maximally homogeneous animal categories. The official animal counts for piglets weighing up to 20 kg animal^{-1}, and for young pigs and fattening pigs weighing at least 20 kg animal^{-1}, have been converted, using the procedure described in HAENEL et al. (2011), into animal counts for the inventory categories "weaners" and "fattening pigs". This transformation has no impact on the total number of swine, however. For purposes of emission calculation, the number of piglets weighing up to 8 kg is deducted from that total number, however. This is done for the reason that piglets weighing up to 8 kg are considered suckling piglets that, with regard to their emissions, are implicitly included in calculations for sows.

The official population numbers for sheep have been corrected for all years as of 2010 (Rösemann et al., 2015). This has been done to take account of the change in the relevant survey date from spring (until 2009, May / June) to 1 March (2010) and to 3 November (since 2011). The correction compensates for the apparent reduction in the number of lambs that this change entails (as well as the corresponding reduction in the total number of sheep).

The numbers of goats in Germany were not surveyed between the years 1977 and 2010. Until 2004, the Federal Ministry of Food and Agriculture (BMEL) estimated goat populations at the national level. As of 2005, the pertinent time series was continued via estimation by the Federal Statistical Office. In 2010, the total number of goats was officially determined for the first time, in the framework of the 2010 agricultural census (LZ 2010). That figure is considerably lower than the estimates used in for earlier years. By agreement with the Federal Statistical Office, those estimates, which are also reported to EUROSTAT, continue to be used in the inventory. No official goat-population figures for 2011 and 2012 were available. The figures for those years were calculated via linear interpolation, using the official goat-population figure for 2013.

In the inventory, population figures for horses are subdivided into the two categories "heavy horses" and "light horses and ponies", to take account of the differences in emissions behaviour between the two categories.

In the 2010 and 2013 agricultural censuses, "numbers of equids", rather than numbers of horses, were counted. The equid figures include the counts for mules and asses.The numbers for mules and asses cannot be separated out of the equid data (included elsewhere, IE). As of the 2015 submission, therefore, the inventory no longer includes "mules and asses" as a separate category. Until the year 2009, the counts for mules and asses were added to the counts for light horses and ponies. In keeping with data of the INTERESSENGEMEINSCHAFT FÜR ESEL UND MAULTIERE (Interest assocation for mules and asses – IGEM)[82], the applicable number for mules and asses has been estimated at 8,500 mules and asses per year. Gaps within the time series for horses have been filled in via linear interpolation.

In official surveys, pullets up to the age of six months are counted, although in common husbandry practice pullets are considered laying hens, when they complete their 18th week of life. For the inventory, therefore, in all years of the time series, a fraction of the pullets was shifted into the laying-hen category. At the same time, the total sum of pullets and laying hens was not changed. In the inventory, the official census data for turkeys were broken down by the categories "turkeys, males" and "turkeys, females", for all years since 1990, to take account of the pertinent differences in emissions behaviour.

No official poultry counts for 2011 and 2012 were available. The figures for those years were calculated via linear interpolation, using the official poultry-population figure for 2013.

5.1.3.2.3 Animal-place data used in the inventory (3.A, 3.B)

Table 162 presents a compilation of the animal-place figures on which German reporting is based. With regard to the uncertainties for the population figures, cf. Table 204 in Chapter 5.1.6.

Table 162: Animal-place figures used in German reporting (3.A, 3.B), in thousands

[in thousands]	Dairy cattle	Other cattle	Swine	Sheep	Goats	Horses	Poultry
1990	6,355	13.133	26.502	3.266	90	499	113.879
1991	5,632	11.502	22.183	3.250	86	519	108.770
1992	5,365	10.843	22.618	2.999	90	539	103.662
1993	5,301	10.597	22.238	3.001	92	573	106.805
1994	5,273	10.690	21.148	2.882	95	607	109.948
1995	5,229	10.661	20.387	2.991	100	634	111.228
1996	5,195	10.565	20.809	2.953	105	661	112.507
1997	5,026	10.201	21.248	2.885	115	602	114.439
1998	4,833	10.110	22.500	2.869	125	543	116.371
1999	4,765	10.132	22.138	2.724	135	484	118.303
2000	4,570	9.969	21.768	2.743	140	500	120.180
2001	4,549	10.055	21.792	2.771	160	515	122.056
2002	4,427	9.561	22.110	2.722	160	524	122.732
2003	4,371	9.274	22.352	2.697	160	533	123.408
2004	4,285	8.912	21.758	2.714	160	521	121.984
2005	4,236	8.800	22.743	2.643	170	508	120.561
2006	4,082	8.668	22.417	2.561	180	530	123.712
2007	4,071	8.617	22.985	2.538	180	551	126.863
2008	4,218	8.754	22.677	2.437	190	521	127.542
2009	4,205	8.742	23.021	2.350	220	491	128.221
2010	4,183	8.629	22.244	2.245	150	462	128.900
2011	4,190	8.340	22.788	1.980	143	462	145.040
2012	4,190	8.319	23.648	1.966	137	461	161.180
2013	4,268	8.418	23.391	1.877	130	461	177.321

5.1.3.2.4 Comparison with livestock-population figures of the FAO (3.A, 3.B)

The FAO publishes livestock-population figures for all countries of the world in an Internet database (FAOSTAT, http://faostat3.fao.org). Many of the livestock-population figures listed in the database differ from the corresponding figures used in the inventory. As a rule, FAOSTAT contains data collected by the Federal Statistical Office in Germany, i.e. its data source is the same as that for the inventory. Small discrepancies can be explained as the result of rounding

[82] Asses and Mules Society

errors and of reconstruction of individual figures that the Federal Statistical Office does not report (such as certain figures of German city-states). The following section explains the larger discrepancies.

Cattle: Unlike the inventory, for the years 2011 – 2013 FAOSTAT contains May-census data (for the same period, the inventory uses data from the November census). For years prior to 2012, minor discrepancies result in that the inventory includes buffalo populations in cattle populations. For the period prior to 2000, the FAO figures have been entered in a year that is one year off the correct year (for example, the cattle-count figures listed for 1999 are actually figures for 1998).

Swine: In general, the swine-population figures listed by the FAO cannot be compared with the corresponding inventory figures, since the inventory always deducts the numbers of piglets that weigh less than 8 kg (cf. Chapter 5.1.3.2.2).

Sheep: As of 2010, the FAO's sheep figures cannot be compared with the corresponding inventory figures, since the inventory figures are always corrected figures (cf. Chapter 5.1.3.2.2). In the periods 1993 – 2000 and 2005 – 2009, the two sets of figures show good agreement. In the remaining periods (1990 – 1992 and 2001 – 2004), there are discrepancies – some of them large – that cannot be explained with the available information.

Goats: The goat-population figures for 2010 and 2013 agree. The inventory uses linear interpolation to obtain figures for the years 2011 and 2012; the origin of the goat-population figures for 2011 and 2012 is unclear. For the period 1991 through 2003, the FAO figures have been entered so as to be one year off the correct year (1991 contains the goat-population figures for 1990, etc…).

Horses: The horse counts for 2013 agree. The FAO figures for 2008 – 2012 are all FAO estimates, although census data for 2010 are available. Those estimates differ considerably from the inventory's corresponding data, which have been obtained via linear interpolation. The inventory figures for the period through 2009 include 8,500 mules and asses in each year; those counts are lacking in the FAO figures (cf. Chapter 5.1.3.2.2).

Poultry: The poultry counts agree for nearly all years with animal censuses (1992, 1994, 1999, 2003, 2005, 2010 and 2013). It seems clear that in FAOSTAT the results of the censuses of the years 1990, 1996 and 2001 have been erroneously entered in the following year in each case. Very large discrepancies are seen especially in the figures for the years 2011 and 2012, which the FAO seems to have extrapolated before the poultry counts for 2013 had become available.

5.1.3.3 Yield, energy and feed data (3.A, 3.B)

To calculate emissions in accordance with a Tier 2 method, one requires data on animal yield (animal weight, weight gain, milk yield, milk protein content, milk fat content, numbers of births, numbers of eggs and weights of eggs) and on the relevant feed (phase feeding, feed components, protein and energy content, energy metabolisability and digestibility of organic matter). To divide the total numbers of turkeys, as reported by the Federal Statistical Office, into cocks and hens, one must know the applicable sex ratio. For the most part, such data are not available from official statistics. In the present case, such data were obtained from the open literature, from association publications, from regulations for agricultural consulting in Germany and via surveys of experts.

Table 163 shows the mean animal weights for dairy cattle, other cattle, swine and poultry. The figures, apart from those for swine, differ from those in the 2014 NIR, since the weight data have been updated for dairy cows and heifers as of 1993 (see below), and since the cattle category now also includes buffalo (cf. Chapter 5.1.3.2.2). Furthermore, in the poultry category, the calculation for the average weight of laying hens has been improved, and for broilers, a fixed average weight of 1 kg per animal is now assumed, as a result of introduction of the new model (see below). For details on calculation of average animal weights, cf. RÖSEMANN et al. (2015).

Table 163: Average animal weights (3.A, 3.B)

[kg animal^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy cattle	607.9	599.1	619.3	628.4	625.5	618.7	628.5	625.8	633.7	638.2
Other cattle	338.7	335.8	346.6	351.8	352.9	351.1	356.0	356.1	362.6	363.3
Swine	66.7	67.4	68.2	68.0	68.3	69.0	69.0	68.8	68.4	67.9
Poultry	1.63	1.66	1.65	1.62	1.60	1.63	1.59	1.62	1.60	1.60
[kg animal^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Dairy cattle	641.9	651.2	645.8	644.6	641.3	646.7	648.6	651.2	642.6	641.9
Other cattle	367.7	372.9	367.0	366.5	364.7	365.4	369.4	371.8	365.7	366.0
Swine	67.3	67.5	67.4	67.7	67.4	67.0	66.9	66.9	66.6	66.7
Poultry	1.67	1.69	1.69	1.78	1.80	1.81	1.83	1.82	1.78	1.80
[kg animal^{-1}]	**2010**	**2011**	**2012**	**2013**						
Dairy cattle	646.8	647.8	646.1	645.7						
Other cattle	367.8	365.6	365.2	367.1						
Swine	65.3	64.1	63.7	63.2						
Poultry	1.78	1.74	1.72	1.69						

The animal weights for sheep, goats and horses (cf. RÖSEMANN et al., 2015) do not enter into the emissions calculations, but they have been estimated for the purposes of CRF-3.B (average weights for sheep and horses, to take account of the inclusion of both large and small animals): Sheep, 50 kg animal^{-1}; goats, 40 kg animal^{-1}; and horses, 490 kg animal^{-1}.

Table 164 shows the mean daily milk yield for dairy cattle; it is obtained by dividing the annual milk yield by 365 days.

Table 164: Average daily milk yield for dairy cows (3.A)

[kg d^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Milk yield	12.93	13.38	14.00	14.28	14.41	14.80	15.12	15.48	15.86	16.22
[kg d^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Milk yield	16.65	17.09	17.41	17.92	18.03	18.53	18.77	19.03	18.69	19.11
[kg d^{-1}]	**2010**	**2011**	**2012**	**2013**						
Milk yield	19.41	19.84	20.06	20.14						

For dairy cattle, heifers, male beef cattle, sows, weaners and fattening pigs, the gross energy (GE) intake is calculated as a function of yield. For such calculations, feeding is assumed to exactly meet animal net-energy-for-lactation (NEL) and metabolisable energy (ME) requirements[83]. The quantity of feed, of a given composition, required to meet NEL and ME energy requirements is calculated on the basis of the energy requirements and the mean NEL and ME energy content of the feed (RÖSEMANN et al., 2015). The GE intake for a given animal is calculated on the basis of the feed quantity ingested and the mean GE content of the feed. The GE intake for calves, suckler cows, male cattle older than 2 years, boars, goats,

[83] The energy requirements for dairy cattle are given in terms of the "net energy for lactation (NEL)" (cf. KIRCHGESSNER et al., 2008), while the term "metabolisable energy (ME)" is used for other animals for which the German inventory includes energy-requirements calculations (for example, cf. GfE, 2006).

sheep and horses are calculated with the help of standard values. No GE intake is calculated for poultry.

With respect to the 2014 NIR, the following yield data, or yield-related data and methods, were changed (cf. also RÖSEMANN et al., 2015):

- **Vacancy periods:** Through the 2014 NIR, vacancy periods between production cycles were included for a number of animal categories (calves, weaners, fattening pigs, laying hens, broilers, ducks, turkeys). After discussing this approach, the EAGER working group[84] concluded it was not compatible with interpretation of official population figures as AAP (cf. Chapter 5.1.3.2). As of the present 2015 NIR, vacancy periods are no longer taken into account.
- **Dairy cattle (activity data, methods):** The slaughter-weight data on which the animal-weight calculations are based have been updated for the period as of 1993. The milk-production data were updated for 2011 and 2012. With the help of improved methods, the Federal Statistical Office has updated the manner in which the population is divided among dairy cattle with mixed diet and grass based diet (see Rösemann et al., 2015, Chapter 4.3.4.1). The birth weight for calves was increased from 36 to 41 kg.
- **Calves (methods):** The calf model has been updated (birth weight; final age as a calf is now four months, instead of two months; GE intake; CH_4 from enteric fermentation; VS, N and TAN excretions). Vacancy periods are no longer taken into account (see above).
- **Heifers, male beef cattle (activity data, methods):** The final ages and weights have been adjusted in accordance with the new final age for calves. For heifers, the birth weight for calves, and slaughter-weight data on which the animal-weight calculations are based, have been updated for the period as of 1993.
- **Swine (methods):** New (national) methane conversion factors for enteric fermentation have been implemented (RÖSEMANN et al., 2015).
- **Sows (methods):** The days open have been updated (shortened); this has increased the number of annual production cycles.
- **Weaners, fattening pigs (methods):** Vacancy periods are no longer taken into account (see above).
- **Sheep:** For lambs, the methods for methane emissions from enteric fermentation, and for manure management, have been changed (RÖSEMANN et al., 2015). The emissions of a lamb are now lower than those of a mature sheep.
- **Poultry (activity data, methods):** Due to a lack of new data, the animal and egg weights for pullets and laying hens had to be carried forward into 2013. The model for broilers has been extensively revised (RÖSEMANN et al., 2015). For broilers, laying hens, ducks and turkeys, vacancy periods are no longer taken into account (see above).

Table 165 shows the daily gross energy (GE) intake for dairy cattle, other cattle and swine. Differences with respect to the corresponding data in the 2014 NIR are seen in all three animal categories. They result from the aforementioned changes in yield data, activity data and methods.

[84] EAGER: European Agricultural Gaseous Emissions Inventory Researchers Network.

Table 165: Mean daily gross energy intake (GE) (3.A)

[MJ place^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy cattle	259.9	263.3	271.0	275.3	275.2	277.8	281.4	283.5	287.9	291.2
Other cattle	103.3	103.2	105.1	105.8	105.4	105.5	105.4	105.9	106.2	107.4
Swine	30.2	31.2	31.4	31.5	31.6	31.8	32.0	32.1	32.3	32.6
[MJ place^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Dairy cattle	295.1	300.3	301.8	305.9	306.7	310.3	311.8	314.7	310.3	314.1
Other cattle	107.0	107.6	106.2	106.2	105.8	105.5	105.8	105.6	105.1	105.5
Swine	32.6	32.8	32.7	32.8	32.8	33.0	33.1	33.2	33.3	33.8
[MJ place^{-1}]	**2010**	**2011**	**2012**	**2013**						
Dairy cattle	317.5	320.3	321.9	322.1						
Other cattle	105.3	104.8	104.3	104.4						
Swine	33.7	34.0	34.3	34.4						

Table 166 through Table 168 show, for dairy cattle, other cattle and swine, the input data for the VS calculation on which the calculation of CH_4 emissions from manure management is based (cf. Chapter 5.3.2.2.1). The data include dry-matter intake, digestibility of organic matter and ash content of feed. The DMI is obtained from the feed intake, taking account of the DMI in the various feed components (cf. RÖSEMANN et al., 2015). The digestibility of organic matter, and the ash content of feed, are given as feed-property data (BEYER et al., 2004; information from producers); where the data are not available, suitable substitute values are used (cf. RÖSEMANN et al., 2015). Differences with respect to the 2014 NIR result from the aforementioned changes in yield data, activity data and methods.

Table 166: Daily dry-matter intake

[kg $^{-1}$ place^{-1} d^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy cattle	14.17	14.34	14.73	14.95	14.94	15.07	15.26	15.36	15.59	15.76
Other cattle	5.52	5.52	5.61	5.65	5.63	5.64	5.63	5.66	5.68	5.73
Swine	1.83	1.90	1.91	1.91	1.92	1.93	1.95	1.95	1.96	1.98
[kg $^{-1}$ place^{-1} d^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Dairy cattle	15.96	16.23	16.30	16.51	16.55	16.74	16.81	16.96	16.73	16.93
Other cattle	5.71	5.75	5.67	5.67	5.65	5.63	5.65	5.64	5.61	5.63
Swine	1.98	1.99	1.98	1.99	1.99	2.00	2.01	2.01	2.02	2.05
[kg $^{-1}$ place^{-1} d^{-1}]	**2010**	**2011**	**2012**	**2013**						
Dairy cattle	17.1	17.2	17.2	17.3						
Other cattle	5.62	5.59	5.59	5.56						
Swine	2.05	2.06	2.06	2.08						

Table 167: Digestibility of organic matter in feed (3.A)

[%]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy cattle	72.9	73.0	73.2	73.3	73.3	73.4	73.5	73.6	73.7	73.8
Other cattle	72.7	72.7	72.7	72.7	72.7	72.7	72.7	72.6	72.7	72.5
Swine	84.8	84.7	84.7	84.7	84.7	84.7	84.7	84.7	84.8	84.8
[%]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Dairy cattle	73.9	74.1	74.1	74.3	74.3	74.4	74.5	74.5	74.4	74.5
Other cattle	72.5	72.5	72.6	72.6	72.6	72.7	72.7	72.7	72.8	72.8
Swine	84.8	84.8	84.8	84.8	84.8	84.8	84.8	84.8	84.8	84.8
[%]	**2010**	**2011**	**2012**	**2013**						
Dairy cattle	74.6	74.6	74.7	74.6						
Other cattle	72.8	72.8	72.84	72.8						
Swine	84.8	84.8	84.86	84.9						

Table 168: Ash content of feed

[kg kg^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy cattle	0.096	0.096	0.095	0.094	0.093	0.093	0.092	0.092	0.092	0.091
Other cattle	0.089	0.089	0.089	0.090	0.090	0.091	0.091	0.091	0.091	0.092
Swine	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056
[kg kg^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Dairy cattle	0.091	0.090	0.090	0.089	0.089	0.089	0.089	0.088	0.089	0.088
Other cattle	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091
Swine	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056
[kg kg^{-1}]	**2010**	**2011**	**2012**	**2013**						
Dairy cattle	0.088	0.087	0.087	0.087						
Other cattle	0.091	0.091	0.091	0.091						
Swine	0.056	0.056	0.056	0.056						

The following chapters present further information relative to animal husbandry – for example, excretion data (N, VS).

Mean percentages of pregnant animals do not enter into any of the animal models used. For cattle, they are reported in CRF Table 3.A, however, in the interest of completeness.

5.1.3.4 N excretions (3.B)

For dairy cattle, heifers, male beef cattle, swine, laying hens, pullets, broilers, ducks and turkeys, males and turkeys, females, N excretions are calculated as a function of yield. For other animals, N-excretion data are taken from the pertinent German literature (cf. RÖSEMANN et al., 2015).

Calculation of N excretions as a function of yield is based on the assumption that feeding precisely meets energy requirements (cf. Chapter 5.1.3.2.4). The N quantity ingested by an animal is obtained from the ingested quantity of feed and the mean N quantity of the feed ration that conforms to relevant national feeding recommendations. Growth-related N retention, N output via products (milk/eggs) and N losses via pregnancy/young are all deducted from the ingested N quantity. The remaining N quantity is the N excretions figure.

The following parameters enter into calculation of N excretions:

- Dairy cattle: milk production, milk-protein content, milk-fat content, animal weight, weight gain, numbers of births per year, feed characteristics
- Heifers and male beef cattle: weight gain, final weight and feed characteristics;
- Swine: animal weight; for sows, also number of piglets per year; for weaners and fattening pigs, also weight gain and feed characteristics;
- Laying hens, pullets, ducks, turkeys: weight gain, final weight, and feed characteristics; for laying hens, also egg production.
- Broilers: gross meat quantities at slaughter, feed characteristics.

For animal categories with grazing, calculated N excretions per animal place and year are broken down into in-pasture and in-stable excretions, since only in-stable excretions can enter into calculation of N_2O emissions in 3.B. Such division of excrements into in-stable and in-pasture categories is based on the relative time proportions for time in stable and time in pasture (cf. also Chapter 19.3.1, Table 408).

Table 169 shows the time series for N excretions in comparison to the corresponding figures in the 2014 NIR. For goats, the N excretions are constant over time (11.0 kg place^{-1} a^{-1}).

Differences in the N excretions, with respect to the 2014 NIR, result from changes in yield data and methods (cf. Chapter 5.1.3.2.4) and in animal-place figures (cf. Chapter 5.1.3.2).

Table 169: N excretions per animal place and year (3.B(b)), as calculated for the 2015 NIR and the 2014 NIR

[kg place^{-1} a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy cattle, 2015	97.6	99.2	102.6	104.4	102.1	102.9	104.5	105.2	107.2	108.4
Dairy cattle, 2014	97.5	99.3	102.7	104.8	102.2	103.1	104.3	104.7	106.3	107.3
Other cattle, 2015	41.2	41.4	42.2	42.6	42.8	43.0	43.0	43.3	43.5	43.8
Other cattle, 2014	41.8	41.9	43.0	43.5	43.3	43.8	44.0	44.1	44.4	44.9
Swine, 2015	12.1	12.4	12.5	12.5	12.6	12.6	12.7	12.7	12.7	12.8
Swine, 2014	11.1	11.3	11.4	11.5	11.5	11.6	11.7	11.7	11.8	11.6
Sheep, 2015	7.7	7.6	7.6	7.8	7.7	7.7	7.8	7.7	7.7	7.9
Sheep, 2014	7.7	7.6	7.6	7.8	7.7	7.7	7.8	7.7	7.7	7.9
Horses, 2015	48.2	48.2	48.2	48.2	48.1	48.1	48.1	48.4	48.7	49.2
Horses, 2014	48.4	48.4	48.5	48.4	48.4	48.3	48.3	48.6	49.0	49.4
Poultry, 2015	0.69	0.70	0.70	0.68	0.67	0.67	0.66	0.67	0.67	0.65
Poultry, 2014	0.68	0.68	0.69	0.66	0.65	0.64	0.64	0.64	0.65	0.63
[kg place^{-1} a^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Dairy cattle, 2015	109.9	112.1	112.3	113.7	114.0	115.3	115.9	116.9	114.3	115.4
Dairy cattle, 2014	108.6	110.7	110.7	111.7	112.0	113.3	113.9	115.1	113.0	114.1
Other cattle, 2015	43.8	43.9	43.5	43.5	43.5	43.3	43.4	43.1	43.0	43.2
Other cattle, 2014	44.9	45.1	44.6	44.7	44.6	44.7	44.7	44.6	44.4	44.5
Swine, 2015	12.7	12.8	12.7	12.8	12.8	12.8	12.8	12.8	12.8	12.9
Swine, 2014	11.6	11.7	11.8	11.7	11.8	11.7	11.7	11.7	11.7	11.6
Sheep, 2015	7.8	7.8	7.8	7.9	7.8	7.8	7.8	7.7	7.7	7.8
Sheep, 2014	7.8	7.8	7.8	7.9	7.8	7.8	7.8	7.7	7.7	7.8
Horses, 2015	49.0	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8
Horses, 2014	49.2	49.0	49.1	49.1	49.1	49.1	49.0	49.0	49.0	49.0
Poultry, 2015	0.68	0.69	0.69	0.70	0.74	0.75	0.75	0.77	0.76	0.77
Poultry, 2014	0.67	0.67	0.66	0.68	0.73	0.74	0.72	0.74	0.73	0.74
[kg place^{-1} a^{-1}]	**2010**	**2011**	**2012**	**2013**						
Dairy cattle, 2015	116.4	117.3	117.6	117.4						
Dairy cattle, 2014	115.3	116.6	116.9							
Other cattle, 2015	43.1	42.9	42.7	42.7						
Other cattle, 2014	44.5	44.4	44.2							
Swine, 2015	12.8	12.9	12.9	12.9						
Swine, 2014	11.6	11.3	11.3							
Sheep, 2015	7.8	7.8	7.8	7.8						
Sheep, 2014	8.2	8.4	8.4							
Horses, 2015	48.8	48.8	48.8	48.8						
Horses, 2014	49.0	49.0	49.0							
Poultry, 2015	0.79	0.77	0.74	0.71						
Poultry, 2014	0.77	0.78	0.79							

Table 170 shows the annual N excretions for the four manure management systems "slurry-based (without digestion)", "straw-based (without deep bedding and without digestion)", "deep bedding (without digestion)" and "digestion"; as well as for "grazing". N excretions are divided into excretions instables and onpastures, in keeping with the relative time proportions for time in stable and time in pasture.

Table 170: Annual N excretions, by manure management systems, for grazing and overall (3.B(b))

[Gg a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total	1610.9	1437.2	1414.0	1408.1	1387.9	1383.7	1392.4	1369.7	1372.5	1367.8
Slurry-based [a]	898,6	798,4	786.0	777.1	858.9	848.0	853.8	839.1	853.5	850.1
Straw-based [b]	447.3	400.7	388.4	388.5	309.3	310.8	312.3	308.9	296.8	293.5
Deep bedding [a]	51.6	43.9	48.0	49.1	51.2	53.1	52.4	51.6	52.4	54.5
Digestion	0.04	0.10	0.14	0.18	0.22	0.54	0.91	1.15	2.61	2.98
Grazing	213.4	194.0	191.5	193.3	168.3	171.3	173.0	169.0	167.2	166.7

[Gg a^{-1}]	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total	1344.9	1363.2	1327.4	1322.3	1292.9	1298.4	1276.3	1287.9	1292.7	1303.2
Slurry-based [a]	823.8	831.1	807.3	801.7	774.1	766.2	733.7	720.5	707.6	696.9
Straw-based [b]	296.2	302.6	298.3	286.5	287.4	285.5	284.7	289.4	289.4	290.5
Deep bedding [a]	57.4	59.4	57.5	71.6	69.7	70.7	70.4	71.5	74.1	75.2
Digestion	4.75	6.76	9.74	11.57	15.05	32.28	48.03	68.18	82.79	102.17
Grazing	162.8	163.3	154.6	151.0	146.7	143.7	139.5	138.4	138.8	138.5
[Gg a^{-1}]	**2010**	**2011**	**2012**	**2013**						
Total	1287.8	1293.2	1311.5	1326.8						
Slurry-based [a]	659.6	640.3	636.3	640.0						
Straw-based [b]	288.8	291.8	297.1	304.6						
Deep bedding [a]	74.5	71.6	71.3	72.1						
Digestion	128.77	156.44	174.48	176.30						
Grazing	136.1	133.0	132.3	133.8						

[a] Without digestion

[b] Without deep bedding and without digestion

5.1.3.5 VS excretions (3.B)

The VS excretions are calculated for dairy cows, other cattle, swine and poultry (exception: geese) using the national procedure of DÄMMGEN et al. (2011):

Equation 5: Calculation of VS excretions

$$VS_{\mathrm{i}} = m_{\mathrm{feed,\,DM,\,i}} \cdot (1 - X_{\mathrm{DOM,\,i}}) \cdot (1 - x_{\mathrm{ash,\,feed}})$$

VS_{i}	VS excretions for animal category i (in kg place^{-1} d^{-1})
$m_{\mathrm{feed,\,DM,\,i}}$	Dry-matter intake, animal category i (in kg place^{-1} d^{-1})
$X_{\mathrm{DOM,\,i}}$	Digestibility of organic matter, animal category i (in kg kg^{-1})
$X_{\mathrm{ash,\,i}}$	Ash content of feed, animal category i (in kg kg^{-1})

To make it possible to obtain a consistent mean value for VS, for poultry, the VS excretions for geese are back calculated from the CH_4 emissions as calculated with the Tier 1 method, with assumed values for B_o (0.39 m^3 kg^{-1}) and *MCF* (0.015 m^3 m^{-3}) (0.055 kg pl^{-1} d^{-1}).

The input data for the VS calculation include: dry-matter intake, digestibility of organic matter and ash content of feed; for a pertinent overview for dairy cattle, other cattle and swine, cf. Chapter 5.1.3.2.4.

The VS excretions, calculated with national input data, for dairy cattle, other cattle, swine and poultry are shown in Table 171. The changes with respect to the 2014 NIR are the result of changes in yield data and in modeling (cf. Chapter 5.1.3.2.4), as well as in the animal-place figures (cf. Chapter 5.1.3.2). In the poultry category, inclusion of geese, which have higher than average VS excretions, has an effect.

Table 171: Daily VS excretions, for dairy cows, other cattle (including buffalo), swine and poultry (including geese) (3.B(a))

[kg place^{-1} d^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy cows	3.47	3.50	3.57	3.61	3.61	3.63	3.67	3.68	3.72	3.75
Other cattle	1.37	1.37	1.39	1.40	1.40	1.40	1.40	1.41	1.41	1.43
Swine	0.26	0.27	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
Poultry	0.023	0.023	0.023	0.022	0.022	0.022	0.022	0.022	0.022	0.022
[kg place^{-1} d^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Dairy cows	3.78	3.83	3.84	3.87	3.87	3.90	3.91	3.94	3.90	3.94
Other cattle	1.43	1.43	1.41	1.41	1.40	1.40	1.40	1.40	1.39	1.39
Swine	0.28	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
Poultry	0.023	0.023	0.023	0.025	0.026	0.026	0.026	0.026	0.026	0.027

[kg place^{-1} d^{-1}]	2010	2011	2012	2013
Dairy cows	3.97	3.99	4.01	4.01
Other cattle	1.39	1.38	1.37	1.38
Swine	0.29	0.30	0.30	0.30
Poultry	0.027	0.026	0.025	0.024

Table 172 shows the daily VS excretions for sheep, goats and horses. For mature sheep, goats and heavy horses, the default VS values pursuant to IPCC (2006), Table 10A-9, have been used. The VS excretions for lambs are set at 40 % of those for mature sheep, in keeping with the relevant lower energy requirements in the lamb category (i.e. in comparison to those for mature sheep) (RÖSEMANN et al., 2015). Similarly, the VS excretions for light horses and ponies have been derived from the VS excretions for heavy horses, in keeping with the energy requirements ratio between the two categories (RÖSEMANN et al., 2015).

Table 172: Daily VS excretions for sheep, goats and horses (3.B(a))

[kg place^{-1} d^{-1}]	*VS*
Mature sheep	0.40
Lambs	0.16
Goats	0.30
Heavy horses	2.13
Light horses and ponies	1.38

The mean-VS-excretions figure for sheep and horses is not a constant, due to variance in the numbers of large and small animals – as shares of the overall population – in the two categories. The annual variation is small, however. For 2013, the daily VS excretions for sheep amount to 0.31 kg place^{-1} d^{-1}, while for horses they are 1.95 kg place^{-1} d^{-1}.

5.1.3.6 Housing systems, storage systems and application techniques (CRF 3.A, 3.B, 3.D)

5.1.3.6.1 Frequency distributions (3.B, 3.D)

The German inventory uses annual frequency distributions for the various husbandry systems (proportions for grazing / housing; proportions for different housing systems), storage systems and manure-application techniques and time allotted to grazing, by animal sub-categories. The data for manure digestion and storage of digestion residues are discussed in Chapter 5.1.3.6.5.

For the years 1990 through 1999, the frequency distributions for the various housing systems, storage systems and application techniques, and the various time periods allotted to grazing, were obtained with the help of the RAUMIS (Regionalisiertes Agrar- und UmweltInformationsSystem für Deutschland – Regionalised Agricultural and Environmental Information System for Germany) agricultural sector model[85]. The data that entered into RAUMIS included specialised national statistics at the sectoral and district levels, standardisation data of the Association for Technology and Structures in Agriculture (KTBL-Normdaten) relative to description of production processes, data from the Economic Accounts for Agriculture (EAA), special evaluations of the Federal Ministry of Food and Agriculture (population-size-class distribution) and survey data. Where relevant statistical data were missing, models were formulated with the aid of experts.

[85] RAUMIS is operated by the Institute for Rural Studies of the Johann Heinrich von Thünen Institute (vTI; until 2008: Federal Agricultural Research Centre (FAL)). For a pertinent introduction, cf. WEINGARTEN (1995); a detailed description is provided in HENRICHSMEYER et al. (1996).

Updating of the aforementioned RAUMIS data was no longer possible after 1999. The first subsequent year for which it was possible to obtain current data was 2010. Those data were provided by the 2010 agricultural census (Landwirtschaftszählung 2010; LZ 2010), as well as by surveys, for calendar year 2010, of agricultural production methods and of manure application. In most cases, gaps between those data and the RAUMIS data of 1999 have been closed via linear interpolation. In some cases, LZ 2010 data were used in the inventory for the period beginning in 1990, however, instead of comparatively uncertain RAUMIS data or data based on comparatively uncertain assumptions. The 2010 agricultural census collected a first set of official data on grazing of sheep, for example; those data have been used for the years as of 1990, in place of earlier assumptions.

For laying hens, data on distribution of housing systems are available for every year as of 1993 (Federal Statistical Office). The gap in the data from 1990 through 1992 has been closed by using the relevant value for 1993.

In addition, the following determinations have been made on the basis of assessments by experts of the Association for Technology and Structures in Agriculture (KTBL):

- Until 2002, 50 % of all calves were housed in tied systems with solid floors and bedding material and 50 % were housed with deep bedding material; as of 2003, as a result of a ban on tied systems, 100 % were housed with deep bedding material.
- For housing of heifers, all straw-based systems are deemed to have solid floors and bedding material, since such systems are the systems most commonly used in Germany.
- For suckler cows, all straw-based systems – except tied systems – are deemed to be deep bedding systems, since they are the systems most commonly used in Germany.

No data are available for the years 2011 through 2013. For this reason, the LZ 2010 data are also used for those years. In an exception, the applicable incorporation periods for liquid manure have been updated for the period as of 2012, to reflect the fact that implementing regulations now specify that liquid manure (including digestion residues) applied to bare soil has to be worked into the soil within 4 hours.

The numbers of air scrubbing systems in swine-housing facilities, through 2012 (this applies to the NH_3 emissions of relevance for 3.D), have been obtained from surveys of the Association for Technology and Structures in Agriculture (KTBL). Since no new data were available for 2013, the corresponding figures from 2012 have been carried forward for that year.

The applicable fractions for anaerobic digestion of liquid and solid manure of cattle, swine and poultry in biogas plants, and the applicable numbers of gas-tight systems for storage of digestion residues, have been re-derived by the KTBL for the entire 1990 – 2013 time series (KTBL, 2014).

Table 408, Table 409 and Table 410 in Annex Chapter 19.3.1 show the applicable distributions of housing systems, storage systems and application techniques, and they provide data on grazing. These tables also include data on digestion of manure from cattle, swine and poultry husbandry, as well as data on application of digestion residues (cf. Chapter 5.1.3.6.5).

The following tables show, for dairy cows, other cattle, swine and poultry, the manner in which animal populations are divided among the various manure management system categories (this partition has to be reported in CRF-3.B(a)).

Table 173: Slurry-based systems without digestion, in % of excreted VS (3.B(a))

[%]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy cows	54.5	54.9	55.1	54.9	70.9	70.9	70.9	70.9	72.0	72.1
Other cattle	59.2	60.3	59.5	58.6	57.8	56.8	56.4	55.8	55.4	55.1
Swine	80.6	80.2	80.4	81.0	87.1	87.2	87.4	87.4	88.8	88.8
[%]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Dairy cows	72.1	72.1	71.9	71.9	71.6	70.3	68.5	66.4	65.0	63.1
Other cattle	53.4	52.5	51.4	50.3	48.9	47.0	45.2	43.3	41.5	39.5
Swine	89.0	89.2	89.2	89.5	89.4	88.4	87.7	86.6	85.9	85.0
[%]	**2010**	**2011**	**2012**	**2013**						
Dairy cows	60.3	57.4	55.8	55.9						
Other cattle	37.2	35.8	35.2	35.2						
Swine	83.2	81.8	80.9	80.7						

Table 174: Straw-based systems without digestion, in % of excreted VS (3.B(a))

[%]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy cows	27.8	27.1	27.0	27.1	15.7	15.7	15.6	15.7	14.6	14.5
Other cattle	19.6	19.0	18.3	18.4	18.2	18.3	18.5	18.6	18.2	18.3
Swine	17.3	17.4	17.2	16.6	11.0	10.9	10.7	10.7	9.4	9.4
Poultry	100.0	100.0	100.0	100.0	100.0	99.9	99.9	99.9	99.7	99.7
[%]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Dairy cows	14.8	14.9	15.1	15.1	15.3	15.4	15.5	15.5	15.5	15.5
Other cattle	18.5	18.9	19.3	17.6	18.1	18.4	18.7	18.9	19.3	19.7
Swine	9.1	8.8	8.6	8.3	8.1	7.8	7.6	7.3	7.0	6.6
Poultry	99.6	99.4	99.1	99.0	98.7	96.8	95.7	94.7	93.9	92.4
[%]	**2010**	**2011**	**2012**	**2013**						
Dairy cows	15.5	15.4	15.3	15.3						
Other cattle	20.2	20.1	19.8	19.8						
Swine	6.4	6.2	5.9	5.9						
Poultry	90.5	89.4	88.9	89.1						

Table 175: Deep bedding systems without digestion, in % of excreted VS (3.B(a))

[%]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy cows	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Other cattle	6.7	6.3	7.3	7.6	8.2	8.7	8.6	8.7	9.0	9.2
Swine	2.2	2.4	2.4	2.4	1.9	1.9	1.9	1.9	1.7	1.6
[%]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Dairy cows	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Other cattle	10.2	10.7	11.2	14.0	14.4	15.0	15.4	16.0	16.7	17.2
Swine	1.6	1.5	1.5	1.4	1.4	1.4	1.3	1.3	1.3	1.3
[%]	**2010**	**2011**	**2012**	**2013**						
Dairy cows	0.0	0.0	0.0	0.0						
Other cattle	17.5	17.4	17.5	17.5						
Swine	1.3	1.3	1.3	1.3						

Table 176: Digestion systems, in % of excreted VS (3.B(a))

[%]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy cows	0.003	0.008	0.011	0.015	0.020	0.049	0.083	0.11	0.25	0.29
Other cattle	0.003	0.007	0.010	0.012	0.014	0.032	0.053	0.07	0.16	0.17
Swine	0.003	0.007	0.010	0.013	0.016	0.041	0.066	0.08	0.18	0.20
Poultry	0.004	0.010	0.015	0.019	0.023	0.056	0.094	0.12	0.26	0.30
[%]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Dairy cows	0.48	0.67	1.01	1.2	1.6	3.1	5.2	7.5	9.0	11.0
Other cattle	0.27	0.38	0.56	0.7	0.9	2.0	2.9	3.9	4.6	5.6
Swine	0.33	0.46	0.66	0.8	1.0	2.4	3.3	4.7	5.8	7.1
Poultry	0.45	0.62	0.89	1.0	1.3	3.2	4.3	5.3	6.1	7.6
[%]	**2010**	**2011**	**2012**	**2013**						
Dairy cows	14.0	17.0	18.7	18.4						
Other cattle	7.1	8.8	9.6	9.8						
Swine	9.1	10.7	12.0	12.1						
Poultry	9.5	10.6	11.1	10.9						

Table 177: Grazing, in % of excreted VS (3.B(a))

[%]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy cows	17.7	17.9	17.9	17.9	13.2	13.2	13.2	13.2	12.9	12.9
Other cattle	14.4	14.4	14.9	15.3	15.7	16.2	16.5	16.8	17.2	17.3
[%]	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Dairy cows	12.5	12.2	11.9	11.7	11.4	11.1	10.8	10.6	10.5	10.3
Other cattle	17.6	17.6	17.5	17.4	17.7	17.7	17.7	17.9	17.9	18.0
[%]	2010	2011	2012	2013						
Dairy cows	10.1	10.2	10.3	10.4						
Other cattle	18.1	18.0	17.8	17.8						

5.1.3.6.2 Bedding material in solid-manure systems

In solid-manure systems, additional nitrogen enters the system via the bedding material. In the inventory, this nitrogen is taken into account in calculation of N_2O and NO emissions from manure management. Table 408 in Chapter 19.3.1 lists the applicable bedding-material quantities, as fresh mass, for the various different animal-housing procedures. With a dry-matter content of 86 %, and an N quantity of 0.58 % in dry matter (cf. RÖSEMANN et al., 2015), the bedding-material N quantities listed in Table 178, for the various animal categories, result. The changes with respect to the 2014 NIR are the result of modifications of animal-place figures (cf. Chapter 5.1.3.2) and methods (cf. Chapter 5.1.3.2.4).

Table 178: Annual totals for N inputs via bedding material, in straw-based systems

[Gg a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy cows	17.1	14.7	13.9	13.8	7.7	7.6	7.6	7.3	6.6	6.4
Other cattle	23.9	20.2	19.8	19.9	20.6	21.1	20.9	20.4	20.3	20.9
Swine	3.18	2.86	2.91	2.79	1.87	1.78	1.80	1.83	1.70	1.65
Sheep	0.83	0.80	0.74	0.76	0.72	0.75	0.75	0.73	0.72	0.70
Goats	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.06	0.06	0.06
Horses	6.54	6.81	7.08	7.51	7.95	8.30	8.65	7.92	7.20	6.47
Poultry	0.80	0.80	0.81	0.84	0.87	0.91	0.95	0.99	1.02	1.05
[Gg a^{-1}]	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Dairy cows	7.1	7.0	6.9	6.8	6.7	6.7	6.5	6.5	6.7	6.7
Other cattle	21.3	21.7	20.9	20.6	20.1	20.3	20.2	20.4	21.1	21.3
Swine	1.58	1.53	1.51	1.48	1.40	1.41	1.36	1.35	1.28	1.26
Sheep	0.70	0.71	0.70	0.70	0.69	0.68	0.65	0.64	0.62	0.60
Goats	0.07	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.11
Horses	6.65	6.83	6.95	7.08	6.92	6.75	7.03	7.30	6.91	6.52
Poultry	1.10	1.15	1.22	1.28	1.28	1.27	1.30	1.34	1.39	1.46
[Gg a^{-1}]	2010	2011	2012	2013						
Dairy cows	6.7	6.7	6.7	6.8						
Other cattle	21.3	20.6	20.5	20.7						
Swine	1.18	1.18	1.19	1.17						
Sheep	0.58	0.51	0.50	0.48						
Goats	0.07	0.07	0.07	0.06						
Horses	6.12	6.12	6.12	6.12						
Poultry	1.52	1.62	1.72	1.82						

5.1.3.6.3 Maximum methane-producing capacity B_o (3.B(b))

For purposes of emission calculation (cf. Chapter 5.3.2.2.1), the methane formation related to manure storage is characterized via the animal-specific maximum methane-producing capacity B_o and the storage-specific methane conversion factor *MCF*. With regard to the *MCF*, cf. Chapter 5.1.3.6.4.

Table 179 shows the B_o values used and the origins of the relevant data. For cattle and swine, the data are national data. For other animals (apart from pullets and geese), IPCC default values have been used. For pullets and geese, conservative B_o values have been assumed (highest IPCC default value). Owing to variations in the population fractions for the various poultry categories, the mean B_o for poultry is not a constant, as Table 180 illustrates. The reason for the change in this time series, with respect to the 2014 NIR, is that geese have been included, for the first time, in the 2015 NIR.

Table 179: Maximum methane-producing capacity B_o (3.B(b))

[m³ kg⁻¹]	B_o	Source
Cattle	0.23	DÄMMGEN et al., 2012a
Swine	0.30	DÄMMGEN et al., 2012a
Sheep	0.19	IPCC, 2006: 10.77 ff
Goats	0.18	IPCC, 2006: 10.77 ff
Horses	0.30	IPCC, 2006: 10.77 ff
Laying hens	0.39	IPCC, 2006: 10.77 ff
Broilers	0.36	IPCC, 2006: 10.77 ff
Ducks	0.36	IPCC, 2006: 10.77 ff
Turkeys	0.36	IPCC, 2006: 10.77 ff
Pullets	0.39	Assumption (see text)
Geese	0.39	Assumption (see text)

Table 180: Maximum methane-producing capacity B_o for poultry (3.B(b))

[m³ kg⁻¹]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Poultry	0.380	0.380	0.378	0.378	0.378	0.378	0.377	0.377	0.376	0.376
[m³ kg⁻¹]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Poultry	0.375	0.374	0.374	0.373	0.373	0.372	0.372	0.372	0.371	0.371
[m³ kg⁻¹]	**2010**	**2011**	**2012**	**2013**						
Poultry	0.370	0.371	0.371	0.371						

5.1.3.6.4 *Methane conversion factors MCF (3.B)*

Table 181 shows the *MCF* values for cattle, broken down by the storage systems commonly used in Germany. The national values proposed by DÄMMGEN et al. (2012a) are in boldface type. In a conservative approach, chosen due to a lack of IPCC default values or national values, the MCF applying to "slurry without natural crust" was used for "slurry with solid cover" (including tent structures), "slurry with floating chopped-straw cover" and "slurry with floating cover foil". The values for deep bedding and pasture were taken from IPCC (2006)-10.44ff.

Table 181: Methane conversion factors *MCF* (in percent of B_o) for cattle (3.B(a))

		MCF [%]
Slurry	Open tank, without natural crust	**17**
	Solid cover	17
	Natural crust	**10**
	Floating cover (chopped straw)	17
	Floating cover (cover foil)	17
	Below slatted floor > 1 month	**17**
Solid manure	Deep bedding and sloped floor	17
	Heap	**2**
Pasture		1

Table 182 lists the methane conversion factors *MCF* for manure storage in swine husbandry. As was the case for the cattle data, the values are national values (DÄMMGEN et al., 2012a, boldface), default values from IPCC (2006)-10.44ff or conservative assumptions in cases in which no *MCF* is known. For cattle, the *MCF* for "deep bedding" is the same as that for slurry without natural crust, and thus the same relationship has been assumed to hold for swine. Free-range management of swine ("pasture") plays a very insignificant role in Germany and is thus not taken into account in the inventory (not occurring, NO).

Table 182: Methane conversion factors *MCF* (in percent of B_o) for swine (3.B(a))

		MCF [%]
Slurry	Open tank, without natural crust	**25**
	Solid cover	25
	Natural crust	**15**
	Floating cover (chopped straw)	25
	Floating cover (cover foil)	25
	Below slatted floor > 1 month	**25**
Solid manure	Deep bedding and sloped floor	25
	Heap	**3**

For storage of manure from other animals (goats, sheep, horses and poultry), the default values from IPCC (2006)-10.44ff have been used (cf. Table 183).

Table 183: Methane conversion factors *MCF* (in percent of B_o) for goats, sheep, horses and poultry (3.B(a))

MCF [%] [a]	
Heap	2
Poultry manure	1.5
Pasture	1

For systems in which manure is digested, a variable *MCF* results, when the various contributions from pre-storage systems, digesters and systems for storage of digestion residues are taken into account (cf. Chapter 5.1.3.6.5).

In CRF 3.B(a), the MCF values for the various national manure management categories are to be reported under "Additional Information". In Germany, the pertinent categories are "slurry-based without digestion", "straw-based without digestion" (heap), "deep bedding without digestion", "digestion" and "pasture". Table 184 shows, for dairy cattle, other cattle and swine, the average methane conversion factors *MCF* (in percent of B_o) for slurry-based systems without digestion.

Table 184: Average methane conversion factors *MCF* (in percent of B_o) for slurry-based systems without digestion (3.B(a))

[%]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy cows	14.3	14.5	14.5	14.5	14.0	14.0	14.0	14.0	14.0	14.0
Other cattle	14.5	14.8	14.9	14.9	14.3	14.4	14.4	14.4	14.4	14.4
Swine	24.7	24.6	24.6	24.6	23.7	23.7	23.7	23.7	23.7	23.7
[%]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Dairy cows	14.0	14.1	14.2	14.2	14.3	14.4	14.5	14.6	14.8	14.9
Other cattle	14.5	14.6	14.7	14.7	14.8	14.9	14.9	15.0	15.1	15.2
Swine	23.5	23.4	23.2	23.1	22.9	22.8	22.6	22.5	22.4	22.2
[%]	**2010**	**2011**	**2012**	**2013**						
Dairy cows	15.1	15.1	15.2	15.1						
Other cattle	15.2	15.3	15.3	15.3						
Swine	22.1	22.1	22.1	22.1						

The *MCF* values for straw-based systems without digestion, deep-straw-bedding systems without digestion and pasture systems are listed in Table 181 through Table 183. Table 185 shows the average methane conversion factors *MCF* for manure management systems with digestion.

Table 185: Average methane conversion factors *MCF* (in percent of B_o) for manure management systems with digestion (3.B(a))

[%]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy cows	3.00	3.00	2.99	2.99	3.02	3.01	3.01	3.01	3.00	3.00
Other cattle	2.99	2.98	2.97	2.96	2.91	2.91	2.90	2.89	2.88	2.88
Swine	3.88	3.87	3.87	3.87	3.86	3.86	3.86	3.85	3.85	3.85
Poultry	1.56	1.56	1.55	1.55	1.55	1.54	1.54	1.54	1.53	1.53
[%]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Dairy cows	3.00	3.00	2.99	2.99	2.98	2.97	2.95	2.93	2.91	2.89
Other cattle	2.87	2.86	2.85	2.84	2.82	2.81	2.79	2.76	2.74	2.71
Swine	3.84	3.84	3.83	3.83	3.82	3.82	3.80	3.78	3.75	3.73
Poultry	1.53	1.52	1.52	1.51	1.51	1.50	1.48	1.46	1.44	1.42
[%]	**2010**	**2011**	**2012**	**2013**						
Dairy cows	2.87	2.85	2.81	2.80						
Other cattle	2.69	2.67	2.62	2.61						
Swine	3.71	3.69	3.65	3.65						
Poultry	1.40	1.38	1.33	1.33						

5.1.3.6.5 Manure digestion and storage of digestion residues (3.B)

Pursuant to IPCC (2006), Table 10.17, anaerobic digestion of manure, and storage of the resulting digestion residues, is a separate storage-system type. In the 2015 NIR, it is covered, in keeping with the German situation, for cattle, swine and poultry (HAENEL und WULF, 2014; RÖSEMANN et al., 2015). The time series for the activity data have been provided by the Association for Technology and Structures in Agriculture (KTBL), which prepared them on the basis of data of the Deutsches Biomasseforschungszentrum (DBFZ; German biomass research centre) (SCHEFTELOWITZ, 2014); cf. KTBL (2014).

Equation 6, using the example of slurry, describes the concept used by KTBL (2014) to determine the relative fractions of manure that undergoes digestion. Equation 6 is used in a similar manner for solid manure and deep bedding (including the N from bedding material). The aggregation into "manure, total" is carried out on the basis of numbers of animals and of animal-specific manure production.

Equation 6: Concept for calculation of the percentage shares of digested manure with respect to total manure production

$$pct_{\mathrm{SL,\,dig,i}}(y) = 100 \cdot \frac{SL_{\mathrm{dig,i}}(y)}{SL_{\mathrm{total,i}}(y)} = 100 \cdot \frac{W_{\mathrm{el,\,dig}}(y) \cdot s_{\mathrm{i}}}{SL_{\mathrm{total,i}}(y)}$$

Where

$pct_{\mathrm{SL,\,dig,\,i}}$	Quantity of digestion residues, as a fraction of the total slurry production for animal category i (in %)
i	Index of the pertinent animal category
y	Year (1990, 1991, …)
$SL_{\mathrm{dig,\,i}}$	Quantity of nitrogen in digestion residues in animal category i (in kg a^{-1})
$SL_{\mathrm{total,\,i}}$	Total slurry production (nitrogen quantity) of animal category i (in kg a^{-1})
$W_{\mathrm{el,\,dig}}$	Annual electrical work of German biogas plants (in $GWh_{el}\ a^{-1}$)
s_{i}	Work-specific substrate input (nitrogen quantity of animal category i) (in kg GWh_{el}^{-1})

KTBL (2014) derived the annual electrical work $W_{\mathrm{el,\,dig}}$, differentiated by German Länder (states) and plant-output classes, from data of the biogas plant registry (Biogasanlagenregister), which lists all 8896 of the biogas plants in Germany that are remunerated in accordance with the Renewable Energy Sources Act (EEG). In addition, KTBL (2014) calculated the work-specific substrate input s_{i} on the basis of data for 1664 biogas plants, and did so separately for cattle slurry, cattle solid manure, swine slurry and poultry manure. Due to a lack of detailed data, the resulting s_i was assumed to be constant for all relevant years. The nitrogen quantities $SL_{total,\ i}$ were derived from the numbers of animals and from the animal-specific slurry and manure production (including N from bedding material).

Table 186 shows the resulting shares for digestion of cattle slurry and solid manure, swine slurry and poultry manure. For swine solid manure, no digestion has been included. Because swine solid manure is produced in small quantities, the pertinent data are unreliable and do not support any reliable estimates. In the GAS-EM inventory model, the data in Table 186 have been interpreted as percentage shares of the N quantities entered into the system via animal excretions and bedding material (if applicable) (cf. Chapters 5.1.3.4 and 5.1.3.6.2) and of the VS excretions (cf. Chapter 5.1.3.5) that undergo digestion.

Table 186: Relative shares of the manure and slurry that undergoes digestion

[%]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total	0.003	0.008	0.011	0.015	0.018	0.045	0.075	0.097	0.219	0.251
Cattle slurry	0.005	0.012	0.017	0.023	0.025	0.060	0.101	0.132	0.301	0.343
Cattle solid manure	0.001	0.002	0.003	0.003	0.005	0.013	0.022	0.029	0.067	0.076
Swine slurry	0.003	0.009	0.012	0.016	0.019	0.047	0.076	0.095	0.199	0.230
Poultry manure	0.004	0.009	0.013	0.017	0.021	0.050	0.083	0.103	0.227	0.263
[%]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Total	0.41	0.57	0.84	1.00	1.33	2.81	4.25	5.97	7.22	8.81
Cattle slurry	0.57	0.80	1.20	1.45	1.95	3.91	6.26	9.00	10.95	13.44
Cattle solid manure	0.12	0.17	0.24	0.29	0.38	0.86	1.27	1.67	1.92	2.34
Swine slurry	0.37	0.52	0.74	0.87	1.16	2.67	3.64	5.18	6.34	7.71
Poultry manure	0.40	0.55	0.79	0.91	1.13	2.92	4.03	5.25	6.13	7.64
[%]	**2010**	**2011**	**2012**	**2013**						
Total	11.2	13.5	14.8	14.8						
Cattle slurry	17.1	21.0	23.2	23.1						
Cattle solid manure	2.9	3.7	4.1	4.1						
Swine slurry	9.8	11.6	12.9	13.1						
Poultry manure	9.3	10.5	11.0	10.7						

The total *MCF* for digestion of manure and slurry in biogas plants, including pre-storage systems and systems for storage of digestion residues, is calculated in accordance with a national method; cf. Equation 7. It expands the approach described in IPCC (2000), p. 4.36, footnote 1/ formula 1 to include pre-storage systems.

Equation 7: Calculation of total *MCF* for digestion of manure and slurry in biogas plants, including pre-storage of substrate and storage of digestion residues

$$MCF\% = MCF\%_{\mathrm{ps}} + (100\,\% - MCF\%_{\mathrm{ps}}) \cdot \left((1-\mu_{\mathrm{rg}}) \cdot L_{\mathrm{prod}} \; + \; \mu_{\mathrm{rg}} \cdot \frac{MCF\%_{\mathrm{residues}}}{100\,\%} \right)$$

Where

$MCF\%$	Total *MCF* for the system "pre-storage system + digester + system for storage of digestion residues" (in %)
$MCF\%_{\mathrm{ps}}$	*MCF* for the pre-storage system (in %)
μ_{rg}	Potential for residual gas production, with respect to B_o (with $0 \le \mu_{\mathrm{rg}} \le 1$ $m^3\ m^{-3}$)
L_{prod}	Relative leakage rate of the digester, with respect to the quantity of CH_4 produced in the digester (with $0 \le L_{\mathrm{prod}} \le 1$ $m^3\ m^{-3}$)
$MCF\%_{\mathrm{residues}}$	*MCF* for the system for storage of residues from slurry digestion (in %)

Table 187 shows the methane conversion factors $MCF\%_{\mathrm{ps}}$ for pre-storage systems. Regarding the derivation, see RÖSEMANN et al. (2015).

Table 187: Methane conversion factors for pre-storage systems (in percent of B_o)

$MCF\%_{ps}$ [%]	
Cattle slurry	1.7
Cattle manure	0.2
Swine slurry	2.5
Poultry manure	0.15

On the basis of KTBL (2014), the potential CH_4 off-gas quantity μ_{rg} with respect to B_o is considered to be 4.6 % (or 0.046 m^3 m^{-3}); cf. RÖSEMANN et al. (2015).

In keeping with BACHMEIER & GRONAUER (2007), BÖRJESSON & BERGLUND (2008), GÄRTNER et al. (2008) and ROTH et al. (2011), the leakage rate of the digester, L_{prod}, is set at 1 %, or 0.01 m^3 m^{-3} (KTBL, 2014).

A leakage rate is assumed even for a gas-tight system for storage of residues from manure digestion; that leakage rate is assumed to be the same as that of the digester. Taking account of the relative share of gas-tight storage systems, with respect to all storage of digestion residues, one obtains Equation 8.

Equation 8: Calculation of *MCF* for systems for storage of digestion residues

$$MCF\%_{\text{residues}} = x_{\text{gts}} \cdot (100 \cdot L_{\text{sto,gt}}) + (1 - x_{\text{gts}}) \cdot MCF\%_{\text{ngts}}$$

Where

$MCF\%_{\text{residues}}$	*MCF* for the system for storage of digestion residues (in %)
x_{gts}	Relative share of gas-tight storage of digestion residues (in kg kg^{-1})
$L_{\text{sto, gt}}$	Relative leakage rate for gas-tight storage of digestion residues ($L_{\text{sto, gt}} = L_{\text{prod}}$)
$MCF\%_{\text{ngts}}$	*MCF* for non-gas-tight systems for storage of digestion residues (in %)

In general, digestion residues are in a liquid state. For non-gas-tight storage of digestion residues, it is assumed that a natural floating crust forms, as a result of co-digestion of energy crops, which increases the dry-matter content in the digestion residues. This type of storage is thus similar to open storage of undigested cattle slurry with a natural floating crust. For this reason, the relevant *MCF* for undigested cattle slurry is used for $MCF\%_{\text{ngts}}$: 10 % (cf. Chapter 5.1.3.6.4).

Table 188 shows the fraction of gas-tight storage of residues from manure digestion, as a percentage share of all storage of residues from manure digestion, and in percent of N inputs. The data were derived by KTBL (2014) from the pertinent input quantities of digestion substrates, broken down by country-output classifications and plant-output classes, as well as by the percentage shares of biogas plants with gas-tight, covered storage of digestion residues, with respect to the output classes prevailing in Germany (SCHEFTELOWITZ, 2014).

Table 188: Percentage shares for storage of digestion residues in gas-tight and non-gas-tight storage systems (in percent of the N inputs in biogas plants)

[%]	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
gas-tight	0.0	0.9	1.8	2.7	3.6	4.5	5.4	6.3	7.2	8.1
non- gas-tight	100.0	99.1	98.2	97.3	96.4	95.5	94.6	93.7	92.8	91.9
[%]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
gas-tight	9.1	10.0	10.9	12.3	13.8	15.2	20.3	25.3	30.4	35.5
non- gas-tight	90.9	90.0	89.1	87.7	86.2	84.8	79.7	74.7	69.6	64.5
[%]	**2010**	**2011**	**2012**	**2013**						
gas-tight	40.6	45.6	57.0	57.0						
non- gas-tight	59.4	54.4	43.0	43.0						

The total *MCF* values resulting from Equation 7, for the systems "pre-storage systems + digester + system for storage of digestion residues", for dairy cattle, other cattle, swine and poultry, are listed in Table 185.

The reduction of CH_4 emissions from manure management that is related to digestion depends on the fraction of manure that is digested, as well as on the relative frequency of gas-tight systems for storage of digestion residues. The pertinent reductions resulting in Germany are given in Chapter 5.3.2.2.3.

Table 189 lists the N_2O emissions that the inventory takes account of for the various relevant sub-systems and manure types. For details, cf. RÖSEMANN et al. (2015). N_2O and NO emissions from agricultural soils, resulting from application of digestion residues, are described in Chapter 5.5.

Table 189: Calculation of N_2O emissions from anaerobic digestion

		Slurry	Solid manure/poultry manure
Pre-storage systems		0	Equation 9
Digester		0	0
System for storage of di-gestion resi-dues	gas-tight	0	0
	non- gas-tight	Equation 10	Equation 10

Equation 9: Calculation of N_2O emissions from systems for pre-storage of solid manure and poultry manure

$$E_{\mathrm{N2O\text{-}N,\,dig,ps}} = (N_{\mathrm{excr,\,dig}} + N_{\mathrm{straw,\,dig}}) \cdot EF_{\mathrm{N2O\text{-}N,\,dig,ps}}$$

Where

$E_{\mathrm{N2O\text{-}N,\,dig,\,ps}}$	N losses via N_2O emissions from pre-storage of solid manure or poultry manure (in kg a^{-1})
$N_{\mathrm{excr,\,dig}}$	Fraction of annual in-stable N excretions that goes to digestion (in kg a^{-1})
$N_{\mathrm{straw,\,dig}}$	Fraction of annual N inputs from bedding material that goes to digestion (in kg a^{-1})
$EF_{\mathrm{N2O\text{-}N,\,dig,\,ps}}$	N_2O-N emission factor for pre-storage of solid manure or poultrymanure (in kg N_2O-N pro kg N)

Equation 10: Calculation of N_2O emissions from non-gas-tight storage of digestion residues

$$E_{\mathrm{N2O\text{-}N,\,dig,ngts}} = (1 - x_{\mathrm{gts}}) \cdot N_{\mathrm{tot,dig,ferm}} \cdot EF_{\mathrm{N2O\text{-}N,\,dig,ngts}}$$

Where

$E_{\mathrm{N2O\text{-}N,\,dig,\,ngts}}$	N losses via N_2O emissions from non-gas-tight storage of digestion residues (in kg a^{-1})
x_{gts}	Relative share of gas-tight storage of digestion residues (in kg kg^{-1})
$N_{\mathrm{tot,\,dig,\,ferm}}$	Total N quantity from digestion residues that leaves the digester (in kg a^{-1})
$EF_{\mathrm{N2O\text{-}N,\,dig,\,ngts}}$	N_2O-N emission factor for non-gas-tight storage of digestion residues (in kg N_2O-N pro kg N)

The N_2O emission factors used in the inventory are listed in Table 190. For details on their derivation, see RÖSEMANN et al. (2015).

Table 190: N_2O-N emission factors for manure pre-storage and for storage of digestion residues

	[kg kg^{-1}]	Solid manure	Poultry manure
Pre-storage systems	$EF_{N2O-N, dig, ps}$	0.001	0.0001
Systems for storage of digestion residues, non-gas-tight	$EF_{N2O-N, dig, ps}$	0.005	0.005

The N quantity in digestion residues at the beginning of storage ($N_{tot, dig, ferm}$) is calculated with inclusion of the N losses from pre-storage. (It is assumed that no N losses from digesters occur.)

The procedure for calculating NO emissions occurring in connection with manure/slurry digestion is similar to that for calculating N_2O emissions. As is customary in the German inventory's sections on manure management (cf. RÖSEMANN et al., 2015), the NO-N emission factor is assumed to be one-tenth of the N_2O-N emission factor.

To calculate the N_2O emissions that result indirectly from agricultural soils, as a result of deposition of reactive nitrogen (cf. Chapter 5.5.2.1.2), one must also calculate the NH_3 emissions that occur in connection with digestion of manure. Table 189 shows that NH_3 emissions are calculated for pre-storage of solid manure and poultry manure, for non-gas-tight storage of digestion residues and for application of digestion residues. In other relevant cases, it is assumed that NH_3 emissions either do not occur or can be neglected. For details on the extensive subject of NH_3-calculation methods, see RÖSEMANN et al. (2015).

Table 191: NH_3 emissions occurring in connection with digestion of manure and slurry (overview)

		Slurry	Solid manure/poultry manure
Pre-storage systems		0	**>0**
Digester		0	0
System for storage of digestion residues	gas-tight	0	0
	non- gas-tight	**>0**	**>0**
Application		**>0**	**>0**

5.1.4 Digestion of energy crops: Concept and activity data

5.1.4.1 The concept, and the manner in which it is taken into account in the CRF tables

The inventory covers the six energy-crop categories that are the most important in Germany in terms of quantities: maize silage, grass silage, whole-plant silage, wheat grain, rye grain and Corn Cob Mix (CCM). They differ only slightly in terms of their key characteristics (N and VS content in dry matter, maximum methane formation potential B_o; cf. KTBL (2014). This makes it possible to treat the total dry matter for all included energy crops as a single energy-crop category. The procedure for calculating the pertinent emissions is similar to that for calculating emissions from digestion of solid manure (cf. Chapter 5.1.3.6.5), with the exception that no pre-storage is included.

In practice, manure and energy crops are normally digested together. Nonetheless, the emissions occurring in connection with digestion of these two substrate categories are calculated separately, with a view to highlighting the contribution that energy-crop digestion makes to the greenhouse-gas balance.

For further details on emission calculation in connection with digestion of energy crops, see RÖSEMANN et al. (2015).

The following emissions are calculated that result, directly or indirectly, from digestion of energy crops, as well as from storage and application of digestion residues:

Digester

- CH_4 (via leakage)

Storage

- CH_4 (via leakage)
- Direct N_2O
- N_2O resulting indirectly from deposition of NH_3 and NO from storage
- NO

Application

- Direct N_2O
- N_2O resulting indirectly from deposition of NH_3 and NO via application
- N_2O resulting indirectly from leaching / surface runoff of the N entering in the soil via application
- NO

The emissions from digesters and storage of digestion residues are described in Chapter 5.9 and reported under 3.J (CRF 3s2). The direct and indirect N_2O emissions occurring as a result of application of digestion residues are described in Chapter 5.5 and reported under 3.D (CRF 3.D: a.2.c, b.1 and b.2). The NO emissions occurring in parallel are reported, in suitably divided form, under CRF 3s2.

5.1.4.2 Activity data and parameters

The activity data used in calculation of the pertinent emissions consist of the total quantities of dry matter that are input into digestion; cf. Table 192. The underlying substrate quantities were derived by KTBL (2014) in connection with digestion of manure (cf. Chapter 5.1.3.6.5).

Table 192: Total dry matter in the energy crops input into biogas plants

[Gg a^{-1}]	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
	3.4	8.2	11.0	14.4	17.8	43.2	72.0	91.2	206.5	235.3
[Gg a^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
	374.6	533.1	768.4	912.5	1,186.1	3,196.8	4,482.6	6,072.6	7,087.1	8,979.7
[Gg a^{-1}]	**2010**	**2011**	**2012**	**2013**						
	11,254.5	14,005.0	15,580.2	16,195.9						

A weighted average B_o value of 0.37 m^3 kg^{-1} was derived from the the B_o values for the six energy-crop categories (KTBL, 2014), using the IPCC default value for the density of methane (0.67 kg m^{-3}). The following weighted averages for the VS and N content resulted (with respect to dry matter): VS content, 0.951 kg kg^{-1}; N content, 0.0141 kg kg^{-1}.

The VS quantity required for calculation of the CH_4 emissions is obtained by multiplying the dry matter by the average VS content; cf. Table 193.

Table 193: Total VS quantity in the energy crops input into biogas plants

[Gg a-1]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	3.2	7.8	10.5	13.7	16.9	41.1	68.5	86.8	196.4	223.8
[Gg a-1]	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	356.2	507.0	730.8	867.8	1,127.9	3,040.2	4,262.9	5,775.1	6,739.9	8,539.7
[Gg a-1]	2010	2011	2012	2013						
	10,703.0	13,318.7	14,816.8	15,402.3						

The N quantities required for calculation of the N emissions are obtained with the help of the relevant N content; cf. Table 194.

Table 194: Total N quantity in the energy crops input into biogas plants

[Gg a-1]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	0.0	0.1	0.2	0.2	0.3	0.6	1.0	1.3	2.9	3.3
[Gg a-1]	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	5.3	7.5	10.8	12.9	16.7	45.1	63.2	85.6	99.9	126.6
[Gg a-1]	2010	2011	2012	2013						
	158.7	197.5	219.7	228.4						

In keeping with KTBL (2014), the leakage rates for digesters and gas-tight systems for storage of digestion residues are considered to be the same as those used in connection with manure digestion (cf. Chapter 5.1.3.6.5).

Table 195 shows the fractions of gas-tight storage of residues of energy-crop digestion, as percentages of the pertinent input fresh mass (KTBL. 2014). The data differ somewhat from those for storage of manure digestion residues (cf. Table 188). The reason for this is (KTBL. 2014) that the total fraction of energy crops, with respect to the manure / energy-crop substrate mix, increases with plant (i.e. facility) size (a relationship that also holds for the covered-system fraction of systems for storage of digestion residues).

Table 195: Percentage shares for systems for gas-tight and non-gas-tight storage of residues from digestion of energy crops (in percent of the fresh mass inputs in biogas plants)

[%]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
gas-tight	0.0	0.9	1.9	2.8	3.8	4.7	5.7	6.6	7.5	8.5
non- gas-tight	100.0	99.1	98.1	97.2	96.2	95.3	94.3	93.4	92.5	91.5
[%]	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
gas-tight	9.4	10.4	11.3	12.8	14.3	15.8	21.1	26.4	31.7	37.0
non- gas-tight	90.6	89.6	88.7	87.2	85.7	84.2	78.9	73.6	68.3	63.0
[%]	2010	2011	2012	2013						
gas-tight	42.2	47.5	59.4	59.4						
non- gas-tight	57.8	52.5	40.6	40.6						

A range of different application methods, and different incorporation periods for cropland and grassland, are used. The available relative-frequency data were obtained from a survey that the Federal Statistical Office conducted in 2011, for the year 2010; cf. Chapter 19.3.1, Table 410. Because no other data are available, these data have been used for all years of the time series.

5.1.5 Activity data for emissions from agricultural soils and crops

5.1.5.1 N_2O emissions from agricultural soils (3.D)

5.1.5.1.1 The N quantities behind direct N_2O emissions (3.D)

Table 196 shows the N quantities, from various sources, that have been used as a basis for calculating direct N_2O emissions pursuant to IPCC (2006)-11.7 (cf. Chapter 5.5.2.1.1).

Since no data on mineral-fertiliser application are collected, the inventory considers the N quantities from mineral-fertiliser application to be the same as the N quantities given by official statistics on sales of mineral fertilisers. To this end, it is assumed that all of the mineral fertiliser sold in the second half of year j and in the first half of year j+1 (quantities which are recorded in Länder-level statistics) is applied in year j+1. This model assumption reflects actual practice in the German agricultural sector, in which the majority of mineral fertiliser is applied in the spring and early summer. Due to a lack of pertinent data, it is not possible to take account of (possible) storage of stocks.

The N quantity applied with manure and manure digestion residues is equivalent to the total N quantity excreted in housing systems, plus any N quantity introduced via bedding material, and minus the losses via N emissions from housing and storage as given by the N-flow concept (manure: Chapter 5.1.2.4; digestion residues from manure digestion: Chapter 5.1.3.6.5

The N quantity that is applied with residues from digestion of energy crops is obtained as the N quantity in the energy crops input into digestion, minus the N losses via emissions from the system for storage of digestion residues.

For each Land (state) in Germany, N quantities from sewage-sludge application are taken from data of the Federal Environment Agency and (since 2009) of the Federal Statistical Office. In the process, the value for 2012 was updated. For 2013, for which a data value was lacking, the value for 2012 was carried forward as an estimate.

The direct N_2O emissions from N excretions during grazing are calculated in proportion to the N quantity excreted in pasture (cf. Chapter 5.1.3.4).

The quantities of N remaining in the soil in crop residues are obtained from the relevant areas under cultivation, yields and crop-specific N content data. The data on areas under cultivation and on fresh-mass yields are reported by the FEDERAL STATISTICAL OFFICE (STATISTISCHES BUNDESAMT; Fachserie 3, Reihe 3). The data are converted into dry-matter yields with the help of dry-matter-content data given by the Fertiliser Ordinance (Düngeverordnung (DüV, 2007)). The relative N quantities contained in crop residues are taken from the Fertiliser Ordinance (DüV, 2007) and from a list prepared by the Institute of Vegetable and Ornamental Crops (IGZ, 2007). The quantities of N removed from relevant areas, for bedding material in animal husbandry, are deducted.

The following changes in the available N quantities have occurred with respect to the 2014 NIR:

- **Mineral fertiliser, manure and manure digestion residues (methods, activity data):** Table 196 shows the applied N quantities, *without any deduction of application-related NH_3-N and NO-N emissions*, as is required by the N_2O-calculation methods in IPCC (2006) (cf. Chapter 5.5.2.1.1). In the manure category, changes in N excretions have also occurred (cf. Chapter 5.1.3.4).
- **Digestion of energy crops:** The 2014 NIR did not yet report on this source.
- **Grazing (activity data):** The changes shown in Table 196 are the result of changes in N excretions (cf. Chapter 5.1.3.4).
- **Crop residues (methods):** In the 2014 NIR, some N contents of crop residues were calculated erroneously. The correction of these errors has led to a sharp decrease in the calculated N quantities.

- **Biological N fixing:** Is no longer included as an emission source, pursuant to IPCC (2006).

Table 196: The N quantities behind direct N_2O emissions from agricultural soils (3.D)

[Gg a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Mineral fertiliser	2163.6	2011.5	1927.2	1810.1	1612.0	1787.3	1769.1	1757.1	1787.2	1901.9
Manure incl. manure digestion residues	1151.6	1027.0	1008.3	1002.8	1007.2	1002.3	1007.9	990.4	991.3	988.2
Residues from digestion of energy crops	0.0	0.1	0.2	0.2	0.3	0.6	1.0	1.3	2.9	3.3
Sewage sludge	27.4	27.4	26.2	26.2	26.2	35.3	35.3	34.1	31.6	31.5
Grazing	213.4	194.0	191.5	193.3	168.3	171.3	173.0	169.0	167.2	166.7
Crop residues	484.3	488.2	439.2	472.8	458.1	497.6	506.6	550.6	558.5	575.5
[Gg a^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Mineral fertiliser	2013.6	1847.0	1791.7	1787.8	1827.8	1778.4	1783.7	1599.8	1807.2	1550.6
Manure incl. manure digestion residues	972.7	987.5	963.7	958.8	937.9	943.6	928.7	938.9	943.4	952.9
Residues from digestion of energy crops	5.3	7.5	10.8	12.9	16.7	45.1	63.2	85.6	99.9	126.6
Sewage sludge	33.0	29.9	28.2	29.3	28.3	27.4	27.0	27.3	27.0	27.3
Grazing	162.8	163.3	154.6	151.0	146.7	143.7	139.5	138.4	138.8	138.5
Crop residues	559.5	599.7	547.0	491.4	637.4	586.5	548.7	551.3	614.6	643.8
[Gg a^{-1}]	**2010**	**2011**	**2012**	**2013**						
Mineral fertiliser	1569.0	1786.5	1640.4	1648.8						
Manure incl. manure digestion residues	945.2	952.8	968.7	980.7						
Residues from digestion of energy crops	158.7	197.5	219.7	228.4						
Sewage sludge	28.0	26.7	26.7	26.7						
Grazing	136.1	133.0	132.3	133.8						
Crop residues	571.5	559.5	604.2	604.2						

5.1.5.1.2 Areas of cultivated organic soils (3.D)

Table 197 shows the applicable areas of cultivated organic soils, broken down by cropland and grassland. The data have been provided by the LULUCF sector. The values for grassland differ from those for the grassland areas that the LULUCF sector reports, since LULUCF includes both the drained-grassland areas shown in Table 197 and undrained wet-grassland areas.

Table 197: Areas of cultivated organic soils (3.D)

[thousands of ha]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total	**1249.7**	**1251.5**	**1253.3**	**1255.0**	**1256.8**	**1258.6**	**1260.4**	**1262.1**	**1263.9**	**1265.7**
Cropland	404.8	401.8	398.7	395.7	392.6	389.6	386.5	383.5	380.4	377.4
Grassland (drained)	844.9	849.7	854.5	859.3	864.2	869.0	873.8	878.6	883.5	888.3
[thousands of ha]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Total	**1267.4**	**1266.8**	**1266.1**	**1265.5**	**1264.8**	**1264.2**	**1263.3**	**1262.4**	**1261.5**	**1259.8**
Cropland	374.3	369.7	365.0	360.4	355.7	351.1	352.0	352.9	353.9	354.5
Grassland (drained)	893.1	897.1	901.1	905.1	909.1	913.1	911.2	909.4	907.6	905.3
[thousands of ha]	**2010**	**2011**	**2012**	**2013**						
Total	**1258.1**	**1256.4**	**1254.7**	**1250.9**						
Cropland	355.2	355.8	356.5	355.5						
Grassland (drained)	902.9	900.6	898.2	895.4						

5.1.5.1.3 Deposition of reactive nitrogen (3.B, 3.D, 3.J)

Deposition of reactive nitrogen is derived from the sums, as calculated in the inventory, of NH_3 and NO emissions from the German agricultural sector. This is carried out for the NH_3 and NO sources "housing and storage" (3.B), "storage of residues from digestion of energy crops" (3.J) and "application and grazing" (3.D). In addition to application of manure and manure digestion residues, "application" also includes application of mineral fertiliser and residues from digestion of energy crops.

Table 198 shows, for sectors 3.B and 3.J, the quantities of reactive nitrogen on which the calculations of indirect N_2O from N deposition are based. Similar data for the sector 3.D are provided in Table 199.

Table 198: Sectors 3.B and 3.J: Reactive nitrogen from deposition of NH_3 and NO

[Gg a-1]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
3.B, Manure incl. manure digestion residues	265.3	232.9	230.8	228.9	225.1	223.5	225.0	222.9	225.5	224.2
3.J, Residues from digestion of energy crops	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
[Gg a-1]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
3.B, Manure incl. manure digestion residues	222.0	225.3	221.7	224.9	220.4	222.7	219.7	222.3	222.1	223.0
3.J, Residues from digestion of energy crops	0.1	0.2	0.2	0.3	0.4	1.0	1.3	1.6	1.8	2.1
[Gg a-1]	**2010**	**2011**	**2012**	**2013**						
3.B, Manure incl. manure digestion residues	217.3	217.7	220.8	222.7						
3.J, Residues from digestion of energy crops	2.4	2.7	2.3	2.4						

Table 199: Sector 3.D: Reactive nitrogen from deposition of NH_3 and NO

[Gg a-1]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
3.D, Total	**403.4**	**365.4**	**352.4**	**349.7**	**324.6**	**336.3**	**336.5**	**333.4**	**335.4**	**343.1**
3.D, Manure, manure digestion residues, mineral fertiliser, grazing	403.4	365.4	352.4	349.6	324.6	336.2	336.4	333.1	334.9	342.5
3.D, Residues from digestion of energy crops	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.5	0.6
[Gg a-1]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
3.D, Total	**345.2**	**348.9**	**339.6**	**337.5**	**337.2**	**331.2**	**337.4**	**335.0**	**345.9**	**358.0**
3.D, Manure, manure digestion residues, mineral fertiliser, grazing	344.2	347.5	337.6	335.1	334.0	322.7	325.2	318.7	327.0	333.8
3.D, Residues from digestion of energy crops	1.0	1.4	2.0	2.4	3.2	8.5	12.2	16.3	18.9	24.1
[Gg a-1]	**2010**	**2011**	**2012**	**2013**						
3.D, Total	**339.9**	**376.2**	**358.4**	**372.0**						
3.D, Manure, manure digestion residues mineral fertiliser, grazing	309.4	338.1	317.9	329.7						
3.D, Residues from digestion of energy crops	30.5	38.1	40.5	42.3						

Discrepancies in the total quantity of reactive nitrogen (sum of Table 198 and Table 199), with respect to the 2014 NIR, are the result of changes in the pertinent yield data and in animal husbandry models (cf. Chapter 5.1.3.2.4); of changes in the animal-place figures (cf. Chapter 5.1.3.2); and of the fact that the 2014 NIR did not yet take account of digestion of energy crops (cf. Chapter 5.1.4).

5.1.5.1.4 Leaching and surface runoff (3.D)

The N quantity available in the soil for leaching and surface runoff is obtained as the sum of the following activity data components:

- N from application of mineral fertiliser, manure and digestion residues (including residues from digestion of energy crops), and from grazing, comprising the quantities of applied / excreted N, less the N losses from direct N_2O emissions and from NH_3, NO and N_2 emissions;
- N from sewage-sludge application, comprising the quantity of N applied, less the N losses via direct N_2O emissions (no NH_3, NO and N_2 emissions are calculated);

- N in crop residues (cf. Chapter 5.1.5.1), less the N losses via direct N_2O emissions and N_2 emissions (no NH_3 and NO emissions are calculated).

With regard to calculation of the NH_3, NO and N_2 emissions mentioned in this list, we refer to RÖSEMANN et al. (2015); with regard to direct N_2O emissions, cf. Chapter 5.5.2.1.1.

Only part of the N quantity available in the soil via these channels is leached out. That fraction is described via the quantity $Frac_{LEACH}$ (cf. IPCC (2006)-11.21). For $Frac_{LEACH}$, Germany uses the IPCC default value 0.30 kg kg^{-1} (IPCC (2006)-11.24, Table 11.3). The quantities of leached nitrogen calculated with it are given in Table 200. Changes, in comparison to the corresponding figures in the NIR 2014, are discussed in Chapter 5.5.5.

Table 200: Leached N quantity (including surface runoff) (3.D)

[Gg a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total	**990.0**	**921.3**	**882.2**	**858.9**	**802.6**	**860.6**	**860.1**	**863.8**	**873.1**	**906.2**
Mineral fertiliser	505.8	472.3	451.5	422.5	378.1	421.8	417.3	415.5	423.2	451.6
Manure incl. manure digestion residues	269.2	241.2	236.2	234.1	236.3	236.6	237.8	234.2	234.7	234.6
Residues from digestion of energy crops	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.7	0.8
Sewage sludge	6.4	6.4	6.1	6.1	6.1	8.3	8.3	8.1	7.5	7.5
Grazing	95.3	86.6	85.4	85.8	74.5	76.3	76.9	75.5	74.9	75.1
Crop residues	113.2	114.7	102.9	110.4	107.5	117.5	119.5	130.2	132.2	136.7
[Gg a-1]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Total	**927.7**	**895.6**	**860.2**	**843.0**	**888.3**	**870.5**	**859.2**	**818.5**	**895.1**	**838.6**
Mineral fertiliser	479.9	437.6	424.3	422.9	436.1	424.2	424.4	378.5	431.3	365.4
Manure incl. manure digestion residues	231.9	233.9	228.2	226.8	223.8	225.1	221.0	222.1	225.2	224.6
Residues from digestion of energy crops	1.2	1.7	2.5	2.9	3.8	10.3	14.5	19.6	23.1	29.0
Sewage sludge	7.9	7.1	6.7	6.9	6.7	6.5	6.4	6.4	6.4	6.4
Grazing	73.5	73.2	69.0	67.2	65.8	64.4	62.4	61.4	62.4	61.5
Crop residues	133.4	142.1	129.5	116.2	152.1	139.9	130.6	130.4	146.7	151.7
[Gg a-1]	**2010**	**2011**	**2012**	**2013**						
Total	**835.3**	**892.6**	**880.4**	**884.7**						
Mineral fertiliser	371.7	422.9	389.6	390.1						
Manure incl. manure digestion residues	223.9	225.5	230.1	232.1						
Residues from digestion of energy crops	36.6	45.6	51.2	53.0						
Sewage sludge	6.6	6.3	6.3	6.3						
Grazing	61.0	59.8	59.6	60.2						
Crop residues	135.4	132.4	143.5	143.0						

5.1.5.2 CO_2 emissions from liming and urea application (3.G-I)

No data on applied quantities of lime fertiliser are available. For this reason, applied quantities are derived from data on domestic product sales. In the process, it is assumed that the quantity applied in year Y (for example, 1990) is the same as the quantity sold in the business year Y-1/Y (i.e., in the example, 1989/1990). For purposes of emissions calculations, the product quantities reported as "CaO" in official statistics (STATISTISCHES BUNDESAMT, Fachserie 4, Reihe 8.2) have been converted into $CaCO_3$ (cf. RÖSEMANN et al., 2015).

Table 201 shows the chronological progression of total quantities of $CaCO_3$, along with the distribution of those quantities among the agricultural and forestry categories. (Emissions from liming in forestry also have to be reported in Sector 3; cf. 5.8.). Table 201 shows the annually applied quantities of lime fertiliser (divided among the agricultural and forestry sectors). Dolomite cannot be listed separately, but it is included in the data (included elsewhere, IE).

Table 201: Quantities of lime fertiliser, listed as $CaCO_3$ (3.G)

[Gg a-1]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total	**2902.0**	**2922.6**	**2804.5**	**2763.8**	**3205.8**	**3736.1**	**3732.5**	**3915.0**	**4322.5**	**4445.0**
Agriculture	2636.4	2661.2	2435.2	2480.3	2856.1	3405.3	3405.2	3580.4	3982.4	4132.7
Forestry	265.6	261.4	369.3	283.6	349.7	330.8	327.3	334.6	340.1	312.2
[Gg a-1]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Total	**4873.1**	**4166.2**	**4324.9**	**3991.0**	**4006.9**	**3820.1**	**3669.4**	**3955.0**	**4087.8**	**3977.5**
Agriculture	4600.0	3898.5	4029.2	3743.1	3820.6	3661.9	3519.5	3801.8	3968.7	3828.7
Forestry	273.1	267.7	295.7	248.0	186.3	158.1	149.9	153.2	119.1	148.8
[Gg a-1]	**2010**	**2011**	**2012**	**2013**						
Total	**3859.1**	**4186.3**	**4334.6**	**4446.5**						
Agriculture	3726.6	4040.0	4195.8	4291.8						
Forestry	132.6	146.3	138.8	154.7						

The CO_2 emissions from urea application are calculated in proportion to the quantities of applied urea listed in Table 202 (including applied urea ammonium nitrate solution). These quantities were derived stoichiometrically (via multiplication by the molar ratio 60/28) from the urea-N quantities reported in official statistics.

Table 202: Urea application, including application of urea ammonium nitrate solution (3.H)

[Gg a-1]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	654.0	**591.4**	**542.6**	**615.0**	**569.3**	**650.8**	**655.7**	**676.4**	**703.9**	**763.4**
[Gg a-1]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
	788.9	**874.2**	**880.1**	**863.8**	**915.7**	**815.4**	**891.5**	**874.1**	**883.5**	**1084.1**
[Gg a-1]	**2010**	**2011**	**2012**	**2013**						
	801.0	**1022.6**	**852.0**	**947.8**						

5.1.5.3 NMVOC emissions from agricultural crops

Table 203 shows the input data for agricultural crops for which NMVOC emissions are calculated pursuant to EMEP (2013)-3D-32 ff (cf. Chapter 5.5.2.1.5). The beginning and end years of the time series are listed, by way of example, for the relevant areas under cultivation and the fresh-mass yields. The data on areas under cultivation and on fresh-mass yields are reported by the FEDERAL STATISTICAL OFFICE (STATISTISCHES BUNDESAMT; Fachserie 3, Reihe 3). The data are converted into dry-matter yields with the help of dry-matter-content data given by the Fertiliser Ordinance (Düngeverordnung (DüV, 2007)). The relative emission duration for wheat, rye, rape and grass have been taken from EMEP (2013)-3D-34, Table A3-2, and applied, analogously, to the other crops involved.

Table 203: Input data for calculation of NMVOC emissions from agricultural crops (overview)

Crop	Area under cultivation [ha]		Fresh mass yield [kg ha-1]		Dry matter content	Relative emission duration
	1990	2013	1990	2013	[kg kg-1]	[a a-1]
Wheat	2419.9	3119.7	6.3	8.0	0.86	0.3
Rye	1067.1	784.5	3.8	6.0	0.86	0.3
Barley	2612.5	1570.6	5.4	6.6	0.86	0.3
Oat	533.5	149	4.5	4.8	0.86	0.3
Triticale	77.4	396.9	5.1	6.6	0.86	0.3
Grain maize	228.4	496.9	6.8	8.9	0.86	0.3
Silage maize	1365.4	2003.2	40.4	39.0	0.28	0.3
Rape	557.5	1460.1	3.0	4.0	0.91	0.3
Root crops	1249.6	600.2	40.6	55.8	0.22	0.3
Grass clover ley, alfalfa, forage grass	856.6	634.1	34.0	34.4	0.2	0.5
Legumes	121.2	74.5	3.6	3.5	0.86	0.3
Pastures and meadows	5417.2	4411.6	31.6	32.3	0.2	0.5

5.1.6 Total uncertainty of all GHG emissions in sector 3

Along with calculation of emissions, the total uncertainty for all GHG emissions in Sector 3 was calculated. This was done in accordance with the "Approach1" procedure described in IPCC (2006), Chapter 3, a procedure based on Gaussian error propagation calculation. By way of convention, it is ignored that such error propagation calculation assumes a normal distribution, a distribution requirement that some of the activity data and emission factors that enter into the calculation do not meet or cannot be verified to meet. For asymmetric distributions, the larger of the two intervals [2.5 percentile; average] and [average; 97.5 percentile] was used, as required by IPCC (2006) for the "Approach 1" procedure. Further details on uncertainties calculation for the German inventory are presented in RÖSEMANN et al. (2015).

Table 204 shows, for the year 2013, the total uncertainty, as calculated with the "Approach1" method, for all emissions of the agricultural sector (Sector 3), including emissions from digestion of energy crops and application of residues from digestion of energy crops. Table 204 also shows the uncertainty for the overall trend since 1990. All emissions values are given in CO_2 equivalents, as obtained using the greenhouse warming potential (GWP) conversion factors specified in IPCC (2006), 25 kg kg^{-1} for CH_4 und 298 kg kg^{-1} for N_2O.

In the interest of clarity, the presentation in Table 204 uses the collective animal categories "other cattle", "swine", "horses" and "poultry", and includes pertinent representative uncertainties for activity data and emission factors. Those uncertainties have been derived from the respective uncertainties for the animal sub-categories included in the collective categories. The results in Table 204 (uncertainty in the level of the overall GHG inventory, and uncertainty in the trend) are in accordance with the results obtained via complete calculation with the animal sub-categories contained in the collective categories (cf. RÖSEMANN et al., 2015).

The uncertainties for the emission factors tend to be considerably higher than those for the activity data, and thus predominate the combined uncertainty in the column "Combined uncertainty as % of total national emissions".

The uncertainty for the emission level of the overall GHG inventory is 37.4 % (valid for the year 2013). It iscaused, to a large extent, by the uncertainties for the N_2O emissions from agricultural soils, as the column "Combined uncertainty as % of total national emissions" indicates. The uncertainty for the trend for the period 1990 – 2013 is 11.8 %.

The considerable reduction in the emissions-level uncertainty, with respect to the corresponding figure in the 2014 NIR (73.1 %; valid for 2012), is due mainly to the considerable reduction of the emission factor for surface runoff and leaching, and the considerable reduction of the uncertainty of that factor, that both have resulted from the transition from the IPCC (1996) guidelines to the IPCC (2006) guidelines. For the same reason, the uncertainty for the trend is noticeably lower in the current 2015 NIR than it was in the 2014 NIR (32.9 %; valid for 1990 – 2012).

Table 204: Total-uncertainties calculation for emissions from Sector 3 (animal husbandry, use of agricultural soils), including digestion of energy crops

Category EntFer = Enteric Fermentation MM = Manure Management DEP = Digestion of Energy Plants	Gas	Base year emissions, in CO_2 equivalents	Year 2013 emissions, in CO_2 equivalents	Activity data uncertainty (half the 95 % confidence interval)	Emission factor uncertainty (half the 95 % confidence interval)	Combined uncertainty (half the 95 % confidence interval)	Contribution to Variance by Category in Year 2013 [A]	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Square of "Uncertainty introduced into the trend in total national emissions" [B]
		(GWP_{CH4} = 25, GWP_{N2O} = 298)										
		Gg a^{-1}	Gg a^{-1}	%	%	%		%	%	%	%	
EntFer, dairy cows	CH_4	19089.1	14380.6	4	40	40.2	81.0	0.02	0.18	0.70	1.04	1.58
EntFer, other cattle	CH_4	14163.3	9176.0	4	40	40.2	33.0	0.03	0.12	1.28	0.67	2.09
EntFer, swine	CH_4	677.7	657.3	4	40	40.2	0.2	0.00	0.01	0.05	0.05	0.00
EntFer, sheep	CH_4	506.0	291.6	10	60	60.8	0.1	0.00	0.00	0.10	0.05	0.01
EntFer, goats	CH_4	11.3	16.3	20	60	63.2	0.0	0.00	0.00	0.01	0.01	0.00
EntFer, horses	CH_4	204.6	191.0	10	60	60.8	0.0	0.00	0.00	0.02	0.03	0.00
MM, dairy cows	CH_4	2646.8	2259.9	4	40	40.2	2.0	0.00	0.03	0.04	0.16	0.03
MM, other cattle	CH_4	2602.9	1494.5	4	40	40.2	0.9	0.01	0.02	0.33	0.11	0.12
MM, swine	CH_4	2684.7	2403.0	4	40	40.2	2.3	0.00	0.03	0.10	0.17	0.04
MM, sheep	CH_4	17.0	9.8	10	60	60.8	0.0	0.00	0.00	0.00	0.00	0.00
MM, goats	CH_4	0.5	0.7	20	60	63.2	0.0	0.00	0.00	0.00	0.00	0.00
MM, horses	CH_4	31.7	29.6	10	40	41.2	0.0	0.00	0.00	0.00	0.01	0.00
MM, poultry	CH_4	89.9	146.1	10	40	41.2	0.0	0.00	0.00	0.04	0.03	0.00
MM, direct N_2O, dairy cows	N_2O	1577.2	1012.6	4	100	100.1	2.5	0.00	0.01	0.37	0.07	0.14
MM, direct N_2O, other cattle	N_2O	1474.3	1029.6	4	100	100.1	2.6	0.00	0.01	0.24	0.07	0.06
MM, direct N_2O, swine	N_2O	548.7	565.2	4	100	100.1	0.8	0.00	0.01	0.14	0.04	0.02
MM, direct N_2O, sheep	N_2O	74.2	42.7	10	300	300.2	0.0	0.00	0.00	0.07	0.01	0.01
MM, direct N_2O, goats	N_2O	4.2	6.1	20	300	300.7	0.0	0.00	0.00	0.01	0.00	0.00
MM, direct N_2O, horses	N_2O	156.1	146.0	10	300	300.2	0.5	0.00	0.00	0.07	0.03	0.01
MM, direct N_2O, poultry	N_2O	37.3	66.1	10	100	100.5	0.0	0.00	0.00	0.05	0.01	0.00

Category	Gas	Base year emissions, in CO_2 equivalents	Year 2013 emissions, in CO_2 equivalents	Activity data uncertainty (half the 95 % confidence interval)	Emission factor uncertainty (half the 95 % confidence interval)	Combined uncertainty (half the 95 % confidence interval)	Contribution to Variance by Category in Year 2013 [A]	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Square of "Uncertainty introduced into the trend in total national emissions" [B]
EntFer = Enteric Fermentation MM = Manure Management DEP = Digestion of Energy Plants		(GWP_{CH4} = 25, GWP_{N2O} = 298)										
		$Gg\ a^{-1}$	$Gg\ a^{-1}$	%	%	%		%	%	%	%	
MM, indirect N_2O, all animals	N_2O	1242.3	1043.6	10	400	400.1	42.2	0.00	0.01	0.10	0.19	0.05
Soils, mineral fertilizers	N_2O	10131.8	7721.2	1	200	200.0	577.8	0.01	0.10	1.63	0.14	2.67
Soils, spreading of manure	N_2O	5392.7	4592.0	60	200	208.8	222.8	0.00	0.06	0.37	5.00	25.16
Soils, sewage sludge	N_2O	128.4	124.8	20	200	201.0	0.2	0.00	0.00	0.05	0.05	0.00
Soils, crop residues	N_2O	2267.8	2829.4	50	200	206.2	82.4	0.01	0.04	2.46	2.57	12.66
Soils, organic soils	N_2O	3096.7	2913.4	1	200	200.0	82.3	0.00	0.04	0.92	0.05	0.85
Soils, grazing	N_2O	1909.0	1191.8	20	200	201.0	13.9	0.00	0.02	0.98	0.43	1.15
Soils, indirect N_2O (deposition)	N_2O	1889.1	1553.6	50	400	403.1	95.0	0.00	0.02	0.02	1.41	1.99
Soils, indirect N_2O (leaching, run-off)	N_2O	3477.1	2932.3	170	230	286.0	170.4	0.00	0.04	0.19	9.05	81.95
DEP, digester and storage	CH_4	0.3	1115.4	10	40	41.2	0.5	0.01	0.01	0.57	0.20	0.37
DEP, storage, direct N_2O	N_2O	0.1	217.6	10	100	100.5	0.1	0.00	0.00	0.28	0.04	0.08
DEP, storage, indirect N_2O (deposition)	N_2O	0.0	11.2	10	400	400.1	0.0	0.00	0.00	0.06	0.00	0.00
DEP, soils, direct N_2O	N_2O	0.2	1049.5	10	200	200.2	10.7	0.01	0.01	2.69	0.19	7.30
DEP, soils, indirect N_2O (deposition)	N_2O	0.0	198.0	10	400	400.1	1.5	0.00	0.00	1.02	0.04	1.04
DEP, soils, indirect N_2O (leaching, run-off)	N_2O	0.0	172.7	10	230	230.2	0.4	0.00	0.00	0.51	0.03	0.26
Liming (agriculture and forest)	CO_2	1276.9	1956.5	1	3	3.2	0.0	0.01	0.03	0.03	0.04	0.00
Application of urea	CO_2	479.6	695.0	1	1	1.4	0.0	0.00	0.01	0.00	0.01	0.00
Total		77889.4	64242.5									
					Percentage uncertainty in total inventory:		37.4			Trend uncertainty (percentage):		11.8

[A] The data in this column describe auxiliary data needed to derive the percentage uncertainty in total inventory in the bottommost cell of this column. In order to calculate the data the calculation procedure provided by IPCC (2006)-3.31, Table 3.2, column H, has been used. However, the head of this column as prescribed by IPCC (2006)-3.31, Table 3.2, column H („Contribution to Variance by Category “) does not correctly describe the data in this column. The head could not be adapted to the meaning of the data in the column and should therefore not be used.
[B] The head of this column as prescribed by IPCC (2006)-3.31, Table 3.2, column M („Uncertainty introduced into the trend in total national emissions“), has been modified in order to match the formula provided by IPCC (2006) and applied in the table above to calculate the data in this column.

5.1.7 Quality assurance and control

General quality control and a quality assurance have been carried out by source-category experts and the Single National Entity, according to the QSE-Handbook.

5.1.7.1 The Thünen Institute's quality management for emissions inventories

The Thünen Institute's quality management for emissions-inventory preparation has been developed in conformance with the IPCC guidelines and the QSE (Chapter 1.6.1) . The framework for the quality management, and the process for carrying it out, are described in detail in the relevant concept (BMELV, 2012) and in the provisions for implementation of the concept (TI, 2012). Documents of importance for quality control are added to the inventory description that is archived by the Single National Entity. The requirements and procedures set forth by the provisions for implementation of the concept were fully complied with. The following section describes the special additional quality controls carried out for the present Submission.

5.1.7.2 Input data, calculation procedures and emissions results

In many parts of the inventory, the detailed data and calculation procedures have not changed from the previous submission. In the previous submission, each of the over 200 calculation tables of emissionsby German Länder (states) and summed city-states as well as national emission totals for CH_4, N_2O, NH_3, NO and particulates, was checked for plausibility, outliers and time-series consistency. The calculation tables contain the relevant intermediate results, detailed calculation results for all sub-categories used in the inventory, derived explanatory indicators and national mean values presented in the NIR 2015 and the CRF tables. In sections with no significant changes, random samples of activity data and calculation results were checked.

Updates and new calculations were systematically checked, with a special focus on the new calculations for biogas and cattle and the key sources for ammonia. In addition to the plausibility checks, extensive sensitivity analyses, using calculation scenarios with mitigation measures, were carried out.

The following section lists the criteria used for this year's tests. These criteria exceed the requirements set forth by the provisions for implementation of the concept.

- Activity data and emissions-determining factors
    - The activity data have been correctly entered.
    - The N flows in the N-flow model are complete and logical.
    - The LULUC and Agriculture sections agree in their reporting regarding the areas of the organic soils under cropland and managed grassland.
    - The time series are consistent.
    - Uncertainties have been correctly reported.
- Emission factors
    - The data for EFs are correct.
    - The time series is consistent.
    - Uncertainties have been correctly reported.
- Calculation methods and results
    - The basic calculations are correct.
    - The overview tables are correct.

- o Uncertainties have been correctly reported.
- o New and changed calculation modules have been correctly implemented and react to sensitivity analyses and mitigation scenarios in a robust and plausible manner.

Results of quality controls:

16. All calculations, in the final version, are correct.
17. Results of the sensitivity analyses: The calculations of nitrogen-gas emissions are plausible and react sensitively to activity data on feed composition and on manure spreading. This indicates that the inventory system can clearly reflect management changes implemented for emission reduction.
18. As a result of use of the new IPCC (2006) guidelines, it was not possible to carry out meaningful consistency checks with the calculations of the previous submission.

After the relevant activity data and place-related emission factors (IEF) had been entered into the Central System of Emissions (CSE) database, the emissions as calculated in the CSE were compared against the emissions results that had been obtained with the GAS-EM inventory model. Similarly, the data in the text were checked for consistency with the data in the data tables.

5.1.7.3 Verification

The national emissions results calculated with the GAS-EM inventory model cannot be compared with other pertinent data from Germany, since no such data are available. As an alternative, the implied emission factors (IEF) and other emissions-relevant figures have been compared with the relevant IPCC default values and with relevant data of other countries. This approach, which is always restricted by the present submission's first-time use of the IPCC (2006) guidelines, is described below in the relevant sub-chapters.

In addition, the German emission calculations have been verified by an external expert, in the framework of a verification project (Zsolt Lengyel, Verico SCE). The results show that the activity data are consistent with other data sources, and that the calculations have been performed in a consistent and correct manner, in accordance with the methodological requirements.

The GAS-EM model is continuously being validated and verified in the framework of the European Agricultural Gaseous Emission inventory Research network (EAGER) and, via module-based tests, by the Association for Technology and Structures in Agriculture (KTBL).

5.1.7.4 Reviews and reports

Recommendations from the Reviews until the 2012 Submission have been completely implemented in previous submissions.

The recommendations from the Individual Review for the 2013 Submission, regarding improved transparency, and justification of the activity data and parameters in the biogas calculations, as well as of the national N_2O emission factor for solid manure, were fulfilled by adding the comprehensive detailed report by RÖSEMANN et al. (2015) to the 2015 Submission and by including references to further relevant documents. In keeping with the request for greater consistency in animal-population figures following the change in the census reference date, the sheep-population figures from 2010 onwards have been recalculated in the present

2015 Submission. The ERT's recommendation that the activity data for mineral-fertiliser application be explicitly presented in the NIR has been implemented in the present 2015 Submission.

The recommendations for the Agriculture sector in the draft ERT report of the Centralized Review of the 2014 Submission have been implemented in the present 2015 Submission.

5.2 Enteric fermentation (3.A)

5.2.1 Category description (3.A)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/-/2	**3.A.1 Enteric Fermentation**	**Dairy Cattle**	**CH4**	**19.089,1**	**(1,57%)**	**14.380,6**	**(1,54%)**	**-24,7%**
L/T/2	**3.A.1 Enteric Fermentation**	**Non-Dairy Cattle**	**CH4**	**14.163,3**	**(1,16%)**	**9.176,0**	**(0,98%)**	**-35,2%**
-/-	3.A.2-4 Enteric Fermentation	Other Animals (buffalo, sheep, goats, horses, swine)	CH4	1.399,5	(0,11%)	1.156,3	(0,12%)	-17,4%

Gas	Method used	Source for the activity data	Emission factors used
CH_4	CS/Tier1/Tier2/Tier3	M/Q/AS/RS/NS	CS/D

The category *Dairy cattle* is the most important emissions source within the category *Enteric fermentation*. It is a key category in terms of emissions level. The reasons for its status as a key category include the high animal weights involved, the high yields involved and – in keeping with the first two factors – the high gross energy intakes involved. The category *Other cattle* (including buffalo) is a key category in terms of emissions level and trend.

CH_4 from enteric fermentation occurs via microbial conversions in animals' digestive tracts. The quantities released per animal and unit of time depend on the animal species in question, individual-animal yield and feed composition.

Germany reports on CH_4 emissions from enteric fermentation of dairy cows, other cattle (calves, heifers, bulls, suckler cows, male cattle older than 2 years), swine (sows, including suckling piglets weighing up to 8 kg per animal, weaner piglets, fattening pigs and boars), sheep, goats and horses.

The CH_4-emissions trend is shaped by decreasing animal populations – for cattle especially, throughout the entire period, and for all animal categories since the early 1990s – and by improved feed digestibility, which is partly offset by increasing GE intake levels in connection with increases in milk production and animal weights.

CH_4 emissions from enteric fermentation, as a percentage of total CH_4 emissions from the German agricultural sector (including CH_4 emissions from digestion of energy crops and storage of residues from digestion of energy crops), has decreased slightly over the years (1990: 81.1 %; 2013: 76.8 %). Overall, CH_4 emissions from enteric fermentation decreased by 28.7 % between 1990 and 2013.

5.2.2 Methodological issues (3.A)

5.2.2.1 Methods (3.A)

CH_4 emissions from enteric fermentation of dairy cattle are calculated using a national method (Tier 3); see below. For other cattle and swine, the calculations are carried out with a Tier 2 method (IPCC, 2006, 10.24 ff); see below. For sheep, goats and horses, calculations are carried out with a Tier 1 method that employs default emission factors (cf. Chapter 5.2.2.2).

In the national method for calculation of CH_4 emissions from enteric fermentation of dairy cattle (DÄMMGEN et al., 2012b), the emission factor is calculated, pursuant to KIRCHGESSNER et al. (1994), as a function of intake of raw fibre, N-free extracts, raw protein and fat:

Equation 11: Calculation of the CH_4 emission factor for dairy cattle (national method)

$$EF_{\mathrm{CH4,ent}} = a \cdot M_{\mathrm{XFi}} + b \cdot M_{\mathrm{NFE}} + c \cdot M_{\mathrm{XP}} + d \cdot M_{\mathrm{XF}} + e$$

Where

$EF_{\mathrm{CH4,\ ent}}$	Emission factor for CH_4 from enteric fermentation (in kg place^{-1} a^{-1} CH_4)
a	Coefficient (a = 0.079 kg kg^{-1})
M_{XFi}	Raw-fibre intake (in kg place^{-1} a^{-1})
b	Coefficient (b = 0.010 kg kg^{-1})
M_{NFE}	Intake of N-free extracts (in kg place^{-1} a^{-1})
c	Coefficient (c = 0.026 kg kg^{-1})
M_{XP}	Intake of raw protein (in kg place^{-1} a^{-1})
d	Coefficient (d = - 0.212 kg kg^{-1})
M_{XF}	Intake of fat (in kg place^{-1} a^{-1})
e	Constant (e = 365 · 0.063 kg place^{-1} a^{-1})

The intake of raw fibre, N-free extracts, raw protein and fat is determined from the basic feed-composition data and from the pertinent quantities of ingested feed (cf. Chapter 5.1.3.2.4).

The methane conversion factor is calculated from those figures, with the help of the gross energy intake (GE) (cf. Chapter 5.1.3.2.4):

$$x_{\mathrm{CH4,GE}} = \frac{\eta_{\mathrm{CH4}} \cdot EF_{\mathrm{CH4,ent}}}{GE}$$

Where

$x_{\mathrm{CH4,\ GE}}$	Methane conversion factor for dairy cattle (in MJ MJ^{-1})
η_{CH4}	Energy content of methane (η_{CH4} = 55.65 MJ (kg CH_4)$^{-1}$)
$EF_{\mathrm{CH4,\ ent}}$	Emission factor for CH_4 from enteric fermentation (in kg place^{-1} a^{-1} CH_4)
GE	Gross energy intake (in MJ place-1 a^{-1} GE)

While the methane conversion factor for dairy cows decreased from 0.070 MJ MJ^{-1} in 1990 to 0.064 MJ MJ^{-1} in 2013, the pertinent emission factor increased, as a result of continuous increases in yield, from 119.4 kg CH_4 per animal place and year for 1990 to 134.9 kg CH_4 per animal place and year for 2013 (cf. Chapter 5.2.2.2).

The Tier 2 method that is used for other cattle and swine calculates the emission factor from the gross energy intake (cf. Chapter 5.1.3.2.4) and the methane conversion factor, in accordance with the following formula:

Equation 12: Calculation of the CH_4 emission factor (Tier 2 method, IPCC (2006), p. 10.31)

$$EF_{\mathrm{CH4,ent}} = GE \cdot \frac{x_{\mathrm{CH4,GE}}}{\eta_{\mathrm{CH4}}}$$

Where

$EF_{\mathrm{CH4,\ ent}}$	Emission factor for CH_4 from enteric fermentation (in kg place^{-1} a^{-1} CH_4)
GE	Gross energy intake (in MJ place-1 a^{-1} GE)
$x_{\mathrm{CH4,\ GE}}$	Methane conversion factor (in MJ MJ^{-1})
η_{CH4}	Energy content of methane (η_{CH4} = 55.65 MJ (kg CH_4)$^{-1}$)

For all other cattle, with the exception of calves, a methane conversion factor of 0.065 MJ MJ^{-1} is used, in keeping with IPCC (2006), Table 10.12. Pursuant to DÄMMGEN et al. (2013), the calf category that is being used as of the present 2015 NIR, including calves with a final age of four months, has a methane conversion factor of 0.041 MJ MJ^{-1}. As a result of changes in the composition of the total population of other cattle, the time series for the average methane conversion factor varies slightly (average: 0.0637 MJ MJ^{-1}; minimum: 0.0636 MJ MJ^{-1}; maximum: 0.0638 MJ MJ^{-1}).

Table 205 shows the national category-specific methane conversion factors for swine (DÄMMGEN et al., 2012c).

Table 205: Methane conversion factors for swine; DÄMMGEN et al. (2012c) (3.A)

	MJ MJ^{-1}
Sows	0.0071
Weaners	0.0044
Fattening pigs	0.0046
Boars	0.0071

With regard to the emission factors calculated with Equation 12, cf. Chapter 5.2.2.2.

A detailed description of calculation of CH_4 emissions from enteric fermentation is provided by RÖSEMANN et al. (2015).

5.2.2.2 Emission factors (3.A)

Table 206 shows the CH_4 emission factors calculated per animal place for enteric fermentation of dairy cattle, other cattle and swine.

Table 206: Animal-place-based CH_4 emission factors, enteric fermentation (3.A)

[kg $^{-1}$ place^{-1} a^{-1}]	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Dairy cattle	120.2	120.7	122.7	123.7	124.0	124.4	125.4	125.7	126.8	127.5
Other cattle	43.1	43.2	43.9	44.2	44.1	44.1	44.0	44.3	44.4	44.9
Swine	1.02	1.06	1.07	1.07	1.07	1.07	1.08	1.08	1.09	1.10
[kg $^{-1}$ place^{-1} a^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Dairy cattle	128.4	129.7	129.9	130.8	130.9	131.8	132.1	132.8	131.9	132.8
Other cattle	44.7	45.0	44.4	44.4	44.2	44.1	44.2	44.1	43.9	44.1
Swine	1.09	1.10	1.09	1.10	1.10	1.10	1.10	1.10	1.10	1.11
[kg $^{-1}$ place^{-1} a^{-1}]	**2010**	**2011**	**2012**	**2013**						
Dairy cattle	133.6	134.3	134.7	134.8						
Other cattle	44.0	43.7	43.5	43.6						
Swine	1.11	1.12	1.12	1.12						

The changes with respect to the 2014 NIR result from the changes, as mentioned in Chapter 5.1.3.2.4, in yield data and methods. In the swine category, the new national methane conversion factors have an especially pronounced effect.

Table 207 shows the emission factors for sheep, goats and horses. The emission factors for sheep and horses vary slightly, because the percentages of large and small animals in the relevant populations are not constant over time. For this reason, the values for 2013 are presented here.

Table 207: Animal-place-based CH_4 emission factors for enteric fermentation in sheep, goats and horses in time-series year 2013 (3.A)

Animal category	***EF*** **[kg place^{-1} a^{-1}]**
Sheep	6.2
Goats	5.0
Horses	16.6

5.2.2.3 Emissions (3.A)

The calculated CH_4 emissions from enteric fermentation, for all German animal husbandry, are listed in Table 208.

Table 208: CH_4 emissions from enteric fermentation (3.A)

[Gg a^{-1} CH_4]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total	**1386.1**	**1228.5**	**1186.2**	**1176.3**	**1175.6**	**1172.0**	**1168.7**	**1135.0**	**1113.9**	**1112.5**
Dairy cattle	763.6	679.8	658.1	655.8	653.8	650.7	651.2	632.0	612.8	607.8
Other cattle	566.5	496.4	476.3	468.3	471.0	470.1	465.3	451.6	449.3	454.5
Swine	27.1	23.6	24.2	23.7	22.6	21.9	22.5	23.0	24.4	24.2
Sheep	20.2	19.7	18.4	18.6	17.8	18.5	18.4	17.9	17.7	17.2
Other mammals [a]	8.6	8.9	9.3	9.9	10.4	10.9	11.3	10.5	9.6	8.8
[Gg a^{-1} CH_4]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Total	**1082.5**	**1093.0**	**1050.4**	**1034.4**	**1005.4**	**996.9**	**973.0**	**971.9**	**990.2**	**993.2**
Dairy cattle	586.9	589.9	575.3	571.7	561.0	558.1	539.3	540.5	556.3	558.3
Other cattle	445.6	452.4	424.4	411.5	394.2	387.9	383.3	380.3	384.3	385.3
Swine	23.8	24.0	24.2	24.5	23.9	25.0	24.7	25.4	25.1	25.7
Sheep	17.2	17.4	17.0	17.1	17.0	16.6	15.9	15.7	15.1	14.7
Other mammals [a]	9.0	9.3	9.5	9.6	9.4	9.3	9.7	10.0	9.6	9.2
[Gg a^{-1} CH_4]	**2010**	**2011**	**2012**	**2013**						
Total	**985.8**	**973.7**	**973.6**	**988.5**						
Dairy cattle	559.0	562.7	564.3	575.2						
Other cattle	379.7	364.8	362.2	367.0						
Swine	24.8	25.5	26.5	26.3						
Sheep	14.0	12.3	12.2	11.7						
Other mammals [a]	8.4	8.4	8.3	8.3						

[a] Other mammals: goats and horses

The emissions chronology since 1990 has been shaped primarily by

- trends in animal populations (inter alia, with a sharp decrease in 1990/1991 following German reunification, followed by a gradual further reduction; swine populations increased again as of the mid-1990s, however, as did dairy cattle populations as of 2006/2007);
- continual increases in yields (milk production, animal weights, weight gains).

5.2.3 Uncertainties and time-series consistency (3.A)

With regard to the uncertainties in the area of methane emissions from enteric fermentation, the reader's attention is called to Table 204 in Chapter 5.1.6 (total uncertainty of the German GHG inventory).

All emissions time series are consistent, since they were calculated with the same method for all years of the report period, and since the input data are also consistent and all data gaps have been filled in.

5.2.4 Category-specific quality assurance / control and verification (3.A)

With regard to quality control and quality assurance, we refer to Chapter 5.1.7.

As part of verification, for 2012 the German animal husbandry data for dairy cattle, other cattle and swine were compared with the corresponding IPCC default values and with relevant data of neighbouring countries, including data of the UK (Table 209 and Table 210). At the time the 2015 NIR was being prepared, the results of other countries' 2015 reports were not yet known. Consequently, while the German data have been taken from the current 2015 report, the other-countries data used for this purpose have been taken from the 2014 report. Such a comparison, based on two different reports that themselves are based on different sets of rules (2014: IPCC (1996b); 2015: IPCC (2006)), is made easier in that the methods for calculating emissions from enteric fermentation did not change via the transition from IPCC (1996b) to IPCC (2006).

Table 209 shows, for dairy cattle, the national mean figure for animal-place-related emission factor (implied emission factor, IEF), GE intake and milk yield (which is the key factor affecting emissions levels). The CH_4-conversion factor is also included. It is used to calculate the fraction of gross energy (GE) intake that is converted into methane energy that is lost with emitted methane (cf. the method description in Chapter 5.2.2.1).

In the group of the ten countries being compared, Germany has the highest IEF figure. On the other hand, Germany calculates with the highest CH_4 conversion factor (a factor based on a national calculation procedure). With the exception of the figures for France, the IEF figures of the other countries are based either on the lower IPCC (1996b, 2000) default factor or on separate national factors that are somewhat lower than the IPCC (1996b) default factor. The French CH_4-conversion factor lies between the IPCC (1996b) default value and the German factor.

To make it possible to compare the various IEF values in a meaningful way, they (including the German value) were converted to a common basis, via multiplication by the ratio between the IPCC (2006) default conversion factor Y_m = 6.5 % and the relevant national conversion factor in each case. After this was done, the German IEF was lower than the IEF values of Belgium, Denmark and the Netherlands. What is more, the converted IEF values correlate in an exact linear manner with the national value for GE intake (R^2 = 1.0000). This is proof to the effect that all countries compared, including Germany, calculate CH_4 from enteric fermentation of the same way, as a function of GE intake.

The correlation between the data for GE intake and for average daily milk yield is less close in Table 209 (R^2 = 0.62), although the latter factor is the factor, in dairy cattle husbandry, that most strongly influences animal energy requirements. The reasons for the scattering in the data sets can include differences in animal weights (weight is an additional yield parameter) and differences in methods for calculating animal energy requirements. The ratio of GE intake to milk yield for German dairy cattle (16.0 MJ kg^{-1}) lies in the middle of the fluctuation range defined by the other relevant countries – from 13.8 MJ kg^{-1} (UK) to 18.5 MJ kg^{-1} (Poland).

The IEF default value in IPCC (2006), 109 kg $place^{-1}$ a^{-1}, seems too low for the majority of central European countries; their IEF values, when converted to IPCC (2006), range from 107.9 to 146.3 kg $place^{-1}$ a^{-1} (average value: 131.4 kg $place^{-1}$ a^{-1}).

Table 209: Methane emissions from enteric fermentation of dairy cattle, in various countries – a comparison of Implied Emission Factors (IEF) for the time-series year 2012

	IEF_{CH4} [kg place^{-1} a^{-1}]	$IEF_{CH4,\ corrected}$ [a] [kg place^{-1} a^{-1}]	CH_4-conversion factor Y_m [MJ MJ^{-1}]	GE intake [MJ place^{-1} d^{-1}]	Milk production [b] [kg place^{-1} d^{-1}]
Austria	118.95	128.86	0.0600	302.3	17.58
Belgium	132.20	143.21	0.0600	335.9	20.57
Czech Republic	118.93	128.84	0.0600	302.2	20.31
Denmark	133.91	146.29	0.0595	343.7	22.94
France	120.03	126.61	0.0616	297.0	18.54
Germany	134.67	137.12	0.0638	321.9	20.06
Netherlands	128.24	142.76	0.0584	334.9	k. A.
Poland	99.64	107.94	0.0600	253.2	13.68
Switzerland	122.59	132.81	0.0600	311.5	22.55
UK	110.71	119.94	0.0600	281.3	20.40
IPCC(1996b)-3-4.11, 4.31, 4.39 (Western Europe)	100		0.06	254.7	11.5
IPCC (2000)-4.13-4.20			0.06	Equation 4.1-4.11	
IPCC(2006)-10.15-10.21, 10.29, 10.72		109	0.065	Equation 10.3-10.16	16.44 [c]

a) National IEF converted to the CH_4-conversion factor of 6.5 % given by IPCC (2006)

b) Equivalent to annual milk production divided by 365 days

c) Calculated from the annual milk production assumed in IPCC (2006), 6,000 kg place^{-1} a^{-1}

Source: Germany: Submission 2015; other countries: UNFCCC 2014; k.A.: no data (keine Angabe)

Table 210 shows the IEF and the GE intakes for the group of other cattle and for all swine combined. The pertinent conversion factors Y_m can be calculated from the IEF and GE intakes, using the method described in Chapter 5.2.2.1. As was the case for dairy cows, to be able to meaningfully compare IEF values, one must convert the values to a common basis. This is done by multiplying them by the ratio between the IPCC (2006) default conversion factor Y_m = 6.5 % and the relevant national conversion factor in each case. Among both uncorrected and corrected IEF, the German IEF is somewhat lower than the average value for all countries being compared. As was the case for dairy cows, an exact linear correlation emerges between the converted IEF values and the national values for GE intake (R^2 = 1.0000). This indicates that, for the "other cattle" category, all countries in the comparison group, including Germany, calculate CH_4 emissions from enteric fermentation as a function of GE intake.

A similar statement can be made for the swine category, once the national IEF values listed in Table 210 are converted to a common basis. In this case, IPCC (2006) does not provide a Y_m default value, and thus the pertinent value from IPCC (1996b) has to be used (0.006 %). What is more, only four data sets (Austria, Denmark, Germany, Switzerland) are available for the comparison.

For both the "other cattle" and swine categories, the IEF default values in IPCC (2006) seem too high for the circumstances prevailing in central Europe.

Table 210: Methane emissions from enteric fermentation of other cattle and swine, in various countries – a comparison of Implied Emission Factors (IEF) for the time-series year 2012

	Other cattle			Swine		
	IEF_{CH4} [kg place^{-1} a^{-1}]	$IEF_{CH4, corrected}$ [a] [kg place^{-1} a^{-1}]	GE intake [MJ place^{-1} d^{-1}]	IEF_{CH4} [kg place^{-1} a^{-1}]	$IEF_{CH4, corrected}$ [a]	GE intake [MJ place^{-1} d^{-1}]
Austria	55.78	60.43	141.74	1.50	1.50	38.00
Belgium	47.56	51.75	121.39	1.50		k. A.
Czech Republic	48.23	52.25	122.55	1.50		k. A.
Denmark	40.00	55.51	130.21	1.10	1.60	40.55
France	50.66	50.81	119.18	0.79		NA
Germany	43.73	44.66	104.75	1.12	1.34	34.03
Netherlands	35.64 [b]	40.04	93.93 [b]	1.50		k. A.
Poland	45.87	49.70	116.57	1.50		k. A.
Switzerland	39.33 [b]	44.04	103.31 [b]	1.06	1.06	26.92
UK	43.06		k. A.	1.50		k. A.
IPCC (1996)-3-4.10, 4.11, 4.39, 4.42 developed countries, Western Europe		48.00	135.10		1.50	38.00
IPCC (2000)-4.13-4.20			Equation 4.1-4.11			
IPCC (2006)-10.15-10.21, 10.28, 10.29, Western Europe	57.00		Equation 10.3-10.16	1.50		Equation 10.3-10.16

a) National IEF converted to the CH_4-conversion factors of 6.5 % for other cattle (pursuant to IPCC (2006)) and 0.6 % for swine (pursuant to IPCC (1996b))

b) Calculated from reported original data

Source: Germany: Submission 2014; other countries: UNFCCC 2013; k.A.: no data (keine Angabe)

5.2.5 Category-specific recalculations (3.A)

For dairy cattle, other cattle and swine, Table 211 through Table 213 show the values, as calculated for the 2015 NIR, for gross energy intake, emission factors and emissions as compared to the corresponding figures in the 2014 NIR. The differences between the 2014 NIR and the 2015 NIR are due primarily to the following changes in yield-determining data and calculation methods:

- **Dairy cattle:** The slight changes in gross energy intake, emission factor and emissions are due to changes in feed composition. Those changes, in turn, result from changes in yield data (animal weight, calf birth weight, milk production) and from changes in the division of populations among dairy cattle with mixed diet and grass based diet (cf. Chapter 5.1.3.2.4).
- **Other cattle:** The reduction in the animal-place-based gross energy intake (GEI) and emission factor results from changes in the relevant model (a shift of the age limit separating calves from heifers / male beef cattle) and from updating of the yield data for heifers (animal weights, calf birth weights) (cf. Chapter 5.1.3.2.4). The higher population figure (inclusion of buffalo; cf. Chapter 5.1.3.2) does not offset these effects, and thus the emissions have decreased from the level reported in the 2014 NIR.

- **Swine:** The increase in the gross energy intake is due directly to the fact that (cf. Chapter 5.1.3.2.4) vacancy periods are no longer taken into account for the categories of weaners and fattening pigs. The reductions in the emission factor and the emissions result from use of the new national methane conversion factors (cf. Chapter 5.2.2.1).

The total CH_4 emissions for all mammals have decreased slightly from the 2014 NIR to the 2015 NIR.

Table 211: Comparison of mean daily gross energy intake as reported in 2015 and as reported in 2014 (3.A)

(MJ/animal)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy cattle, 2015	259.9	263.3	271.0	275.3	275.2	277.8	281.4	283.5	287.9	291.2
Dairy cattle, 2014	259.8	263.3	271.0	276.0	275.7	278.6	282.3	284.2	288.6	291.9
Other cattle, 2015	103.3	103.2	105.1	105.8	105.4	105.5	105.4	105.9	106.2	107.4
Other cattle, 2014	105.7	105.3	107.8	108.8	107.5	108.4	108.5	108.5	109.2	110.7
Swine, 2015	30.2	31.2	31.4	31.5	31.6	31.8	32.0	32.1	32.3	32.6
Swine, 2014	27.3	27.9	28.2	28.4	28.6	28.8	29.1	29.1	29.5	29.2
(MJ/animal)	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Dairy cattle, 2015	295.1	300.3	301.8	305.9	306.7	310.3	311.8	314.7	310.3	314.1
Dairy cattle, 2014	295.8	301.2	302.6	306.1	306.9	310.5	312.0	315.0	311.1	314.3
Other cattle, 2015	107.0	107.6	106.2	106.2	105.8	105.5	105.8	105.6	105.1	105.5
Other cattle, 2014	110.5	111.2	109.8	109.7	109.3	109.5	109.7	109.7	109.1	109.4
Swine, 2015	32.6	32.8	32.7	32.8	32.8	33.0	33.1	33.2	33.3	33.8
Swine, 2014	29.3	29.7	29.8	29.6	29.9	29.8	29.9	30.0	30.0	30.0
(MJ/animal)	**2010**	**2011**	**2012**	**2013**						
Dairy cattle, 2015	317.5	320.3	321.9	322.1						
Dairy cattle, 2014	317.7	320.4	321.0							
Other cattle, 2015	105.3	104.8	104.3	104.4						
Other cattle, 2014	109.3	108.9	108.6							
Swine, 2015	33.7	34.0	34.3	34.4						
Swine, 2014	30.0	29.6	29.7							

Table 212: Comparison of animal-place-based CH_4 emission factors (enteric fermentation) as reported in 2015 and in 2014 (3.A)

[kg place^{-1} a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy cattle, 2015	120.2	120.7	122.7	123.7	124.0	124.4	125.4	125.7	126.8	127.5
Dairy cattle, 2014	120.2	120.7	122.7	124	124.1	124.7	125.8	126.1	127.3	128.1
Other cattle, 2015	43.1	43.2	43.9	44.2	44.1	44.1	44.0	44.3	44.4	44.9
Other cattle, 2014	44.3	44.2	45.2	45.6	45.1	45.5	45.5	45.5	45.8	46.5
Swine, 2015	1.02	1.06	1.07	1.07	1.07	1.07	1.08	1.08	1.09	1.10
Swine, 2014	1.08	1.1	1.11	1.12	1.13	1.13	1.15	1.14	1.16	1.15
[kg place^{-1} a^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Dairy cattle, 2015	128.4	129.7	129.9	130.8	130.9	131.8	132.1	132.8	131.9	132.8
Dairy cattle, 2014	129	130.3	130.6	131.3	131.4	132.3	132.6	133.3	132.5	133.2
Other cattle, 2015	44.7	45.0	44.4	44.4	44.2	44.1	44.2	44.1	43.9	44.1
Other cattle, 2014	46.4	46.7	46.1	46	45.9	45.9	46	46	45.7	45.9
Swine, 2015	1.09	1.10	1.09	1.10	1.10	1.10	1.10	1.10	1.10	1.11
Swine, 2014	1.15	1.17	1.17	1.16	1.18	1.17	1.18	1.18	1.18	1.18
[kg place^{-1} a^{-1}]	**2010**	**2011**	**2012**	**2013**						
Dairy cattle, 2015	133.6	134.3	134.7	134.8						
Dairy cattle, 2014	133.9	134.5	134.6							
Other cattle, 2015	44.0	43.7	43.5	43.6						
Other cattle, 2014	45.9	45.7	45.5							
Swine, 2015	1.11	1.12	1.12	1.12						
Swine, 2014	1.18	1.17	1.17							

Table 213: Comparison of CH_4 emissions (enteric fermentation) as reported in 2015 and in 2014 (3.A)

[Tg a⁻¹ CH₄]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
All mammals, 2015	**1.386**	**1.228**	**1.186**	**1.176**	**1.176**	**1.172**	**1.169**	**1.135**	**1.114**	**1.113**
All mammals, 2014	**1.409**	**1.247**	**1.207**	**1.199**	**1.194**	**1.195**	**1.193**	**1.156**	**1.137**	**1.137**
Dairy cattle, 2015	0.764	0.680	0.658	0.656	0.654	0.651	0.651	0.632	0.613	0.608
Dairy cattle, 2014	0.764	0.68	0.658	0.657	0.654	0.652	0.653	0.634	0.615	0.61
Other cattle, 2015	0.567	0.496	0.476	0.468	0.471	0.470	0.465	0.452	0.449	0.455
Other cattle, 2014	0.582	0.508	0.49	0.483	0.482	0.485	0.481	0.464	0.463	0.471
Swine, 2015	0.0271	0.0236	0.0242	0.0237	0.0226	0.0219	0.0225	0.0230	0.0244	0.0242
Swine, 2014	0.0285	0.0244	0.0251	0.0249	0.0238	0.0231	0.0238	0.0243	0.0261	0.0254
[Tg a⁻¹ CH₄]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
All mammals, 2015	**1.082**	**1.093**	**1.050**	**1.034**	**1.005**	**0.997**	**0.973**	**0.972**	**0.990**	**0.993**
All mammals, 2014	**1.108**	**1.119**	**1.076**	**1.058**	**1.029**	**1.021**	**0.997**	**0.997**	**1.015**	**1.016**
Dairy cattle, 2015	0.587	0.590	0.575	0.572	0.561	0.558	0.539	0.541	0.556	0.558
Dairy cattle, 2014	0.59	0.593	0.578	0.574	0.563	0.56	0.541	0.543	0.559	0.56
Other cattle, 2015	0.446	0.452	0.424	0.412	0.394	0.388	0.383	0.380	0.384	0.385
Other cattle, 2014	0.462	0.469	0.44	0.427	0.409	0.404	0.399	0.396	0.4	0.401
Swine, 2015	0.0238	0.0240	0.0242	0.0245	0.0239	0.0250	0.0247	0.0254	0.0251	0.0257
Swine, 2014	0.0251	0.0255	0.0259	0.026	0.0256	0.0266	0.0264	0.0272	0.0267	0.0272
[Tg a⁻¹ CH₄]	**2010**	**2011**	**2012**	**2013**						
All mammals, 2015	**0.986**	**0.974**	**0.974**	**0.989**						
All mammals, 2014	**1.007**	**0.993**	**0.992**							
Dairy cattle, 2015	0.559	0.563	0.564	0.575						
Dairy cattle, 2014	0.56	0.564	0.564							
Other cattle, 2015	0.380	0.365	0.362	0.367						
Other cattle, 2014	0.396	0.381	0.379							
Swine, 2015	0.0248	0.0255	0.0265	0.0263						
Swine, 2014	0.0262	0.0266	0.0276							

5.2.6 Planned improvements (category-specific) (3.A)

No further improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

5.3 Manure management (3.B)

5.3.1 Category description (3.B)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/-	3.B.1 Manure Management	Dairy Cattle	CH4	2.646,8	(0,22%)	2.259,9	(0,24%)	-14,6%
-/-/2	3.B.1 Manure Management	Dairy Cattle	N2O	1.577,2	(0,13%)	1.012,6	(0,11%)	-35,8%
-/-	3.B.1 Manure Management	Non-Dairy Cattle	CH4	2.602,9	(0,21%)	1.494,5	(0,16%)	-42,6%
-/-	3.B.1 Manure Management	Non-Dairy Cattle	N2O	1.474,3	(0,12%)	1.029,6	(0,11%)	-30,2%
-/-	3.B.2-4Manure Management	Other Animals (pigs, buffalo, sheep, goats, horses,poultry)	N2O	234,5	(0,02%)	194,9	(0,02%)	-16,9%
-/-	3.B.2-4 Manure Management	Other Animals (pigs, buffalo, sheep, goats, horses, poultry)	CH4	49,2	(0,00%)	40,1	(0,00%)	-18,4%
L/-	**3.B.3 Manure Management**	**Swine**	**CH4**	**2.684,7**	**(0,22%)**	**2.403,0**	**(0,26%)**	**-10,5%**
-/-	3.B.3 Manure Management	Swine	N2O	548,7	(0,05%)	565,2	(0,06%)	3,0%
-/-	3.B.4 Manure Management	Poultry	CH4	89,9	(0,01%)	146,1	(0,02%)	62,4%
-/-	3.B.4 Manure Management	Poultry	N2O	37,3	(0,00%)	66,1	(0,01%)	77,4%
-/-/2	3.B.5	Wirtschaftsdünger (Atmosphärische Deposition)	N2O	1.242,3	(0,10%)	1.043,6	(0,11%)	-16,0%

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 1 / Tier 2	M/Q/AS/RS/NS	CS/D
N_2O direct	Tier 1 / Tier 2	M/Q/AS/RS/NS	CS/D
N_2O indirect	Tier 1	M/Q/AS/RS/NS	D
NO_X	Tier 1 / Tier 2	M/Q/AS/RS/NS	CS
NMVOC	Tier 1	RS/NS	D

The category *Manure management* is a key category, pursuant to Tier 2 analysis, for CH_4 and N_2O emissions from the categories of a) dairy cattle and b) non-dairy cattle

In Sector 3.B, Germany reports on CH_4, N_2O, NO and NMVOC emissions from manure management

CH_4 is produced by methanogenic bacteria when they break down organic substances in anaerobic environments. Direct N_2O emissions are produced by nitrification and denitrification processes that take place during storage of manure and of digestion residues. NO is produced via nitrification in surface layers of manure storage facilities. NMVOC emissions are released from silage fodder and from manure storage facilities.

Reporting on the manure management also covers indirect N_2O emissions. Such emissions occur in connection with decomposition processes in the soil, and they are generated from reactive nitrogen originating via deposition of NH_3 and NO from management of manure and of digestion residues, as well as via leaching and surface runoff from management of manure and of digestion residues. For reasons of water protection, seeping/leachage and uncontrolled above-ground runoff from management of manure and of digestion residues are to be prevented (cf. in this regard the 1998 NRW Ordinance on facilities for management of slurry, liquid manure and silage seepage (JGS-Anlagenverordnung NRW 1998) and the 2010 Federal Water Resources Act (Wasserhaushaltsgesetz – WHG)). For this reason, no indirect N_2O

emissions from leachage / surface runoff have been calculated. This procedure has been followed for all years as of 1990. With regard to total N_2O emissions from the German agricultural sector, this amounts to a conservative assumption, since the nitrogen that is not lost via N_2O from leaching / surface runoff is applied to fields, thereby causing higher N_2O emissions as a result.

The relevant emissions are calculated in relation to a range of factors, including animal category; animal excretions (which, in turn, are a function of animal yield and of diet); the amounts of time spent by relevant animals in various defined areas (pastures, stables); the types of stables used; nitrogen inputs from bedding material (straw); and the type of manure storage involved.

The CH_4 emissions from manure management (including manure digestion residues and grazing) decreased by 21.4 % between 1990 and 2013. This decrease is due primarily to changes in animal populations and to emissions reductions achieved via manure digestion (cf.

Table 217). In 1990, the CH_4 emissions from Sector 3.Baccounted for 18.9 % of total CH_4 emissions from the German agricultural sector. The corresponding percentage in 2013 was 19.7 %.

The total direct N_2O emissions from manure management (including manure digestion residues but not including grazing which is reported in 3.D) decreased by 25.9 % between 1990 and 2013. The reasons for this decrease are largely the same as those for the decrease in CH_4 emissions; see above. In 1990, the N_2O emissions from Sector 3.B accounted for 11.6 % of total N_2O emissions from the German agricultural sector. The corresponding percentage in 2013 was 9.8 %.

The indirect N_2O emissions assigned to manure management (including manure digestion residues) decreased by 16.0 % from 1990 to 2013. Their share of total N_2O emissions from the German agricultural sector decreased slightly: 1990: 3.7 %; 2013: 3.5 %.

The total NMVOC emissions from manure management amounted to 271.4 Gg a^{-1} in 1990. In 2013, they had decreased by 26.9 %, to 198.4 Gg a^{-1}.

5.3.2 Methane emissions from manure management (3.B, CH_4)

5.3.2.1 Category description (3.B, CH_4)

Cf. Chapter 5.3.1.

5.3.2.2 Methodological issues (3.B, CH_4)

5.3.2.2.1 Methods (3.B, CH_4)

For all animal categories except for geese, CH_4 emissions are calculated in accordance with the Tier 2 method:

Equation 13: Calculation of total CH_4 emissions from manure management

$$E_{\mathrm{CH4,MM}} = \sum_{\mathrm{i,\,j}} n_{\mathrm{i}} \cdot EF_{\mathrm{i,\,j}} = \sum_{\mathrm{i,\,j}} n_{\mathrm{i}} \cdot \alpha \cdot \rho_{\mathrm{CH4}} \cdot VS_{\mathrm{i}} \cdot B_{\mathrm{o,i}} \cdot MS_{\mathrm{i,\,j}} \cdot MCF_{\mathrm{i,\,j}}$$

Where

$E_{\mathrm{CH4,\,MM}}$	Total methane emissions from manure management (in kg a^{-1} CH_4)
n_{i}	Number of animal places in animal category i (in places)

$EF_{i,j}$	Methane emission factor for animal category i in manure management system j (in kg place^{-1} a^{-1} CH_4)
α	Factor for conversion of time units (α = 365 d a^{-1})
ρ_{CH4}	Density of methane (ρ_{CH4} = 0.67 kg m^{-3})
VS_i	VS excretions for animal category i (in kg place^{-1} d^{-1})
$B_{o,i}$	Maximum methane-producing capacity for animal category i (in m^3 kg^{-1} CH_4)
$MS_{i,j}$	Relative proportion of housing places, for animal category i, whose excrement occurs in manure management system j (in place place^{-1})
$MCF_{i,j}$	Methane-conversion factor for manure management system j (in m^3 m^{-3}) [86]

With regard to the number of animal places n_i, the reader's attention is called to Chapter 5.1.3.2.3. The VS excretions are described in Chapter 5.1.3.5. With regard to the relative percentages of systems for storage of solid manure, slurry and digestion residues, and to time allotted to grazing, cf. Chapters 5.1.3.6.1 and 19.3.1. The methane-formation rate B_o and the methane conversion factors MCF are discussed in Chapters 5.1.3.6.3 and 5.1.3.6.4. According to IPCC, manure digestion, including storage of manure digestion residues, is a separate storage type. The B_o and *MCF* values for it are covered in Chapter 5.1.3.6.5.

For geese, the Tier 1 method is used. Since IPCC (2006) does not provide a Tier 1 emission factor for geese, the poultry value given in IPCC(1996b)-3-4.47, 0.078 kg pl^{-1} a^{-1} CH_4, is used.

5.3.2.2.2 Emission factors (3.B, CH_4)

Table 214 shows the time series for the emission factors referenced to animal place. With the exception of the factor for geese, they were calculated in accordance with Equation 13 in Chapter 5.3.2.2.1. The emission factors include the emissions reduction effects resulting via manure digestion. Differences with respect to the 2014 NIR result from changes in yield data and methods (cf. Chapter 5.1.3.2.4) and in animal-place figures (cf. Chapter 5.1.3.2).

Table 214: Animal-place-based CH_4 emission factors; manure management (3.B(a))

[kg place^{-1} a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy cattle	16.7	17.1	17.5	17.6	21.2	21.3	21.5	21.5	22.1	22.3
Other cattle	7.9	8.1	8.3	8.3	8.0	8.0	7.9	7.9	8.0	8.1
Swine	4.1	4.2	4.2	4.3	4.4	4.4	4.4	4.4	4.5	4.5
Sheep	0.21	0.20	0.20	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Goats	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Horses	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.6	2.6
Poultry	0.032	0.032	0.032	0.031	0.031	0.031	0.030	0.031	0.031	0.030
[kg place^{-1} a^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Dairy cattle	22.4	22.9	23.0	23.3	23.4	23.3	23.2	23.0	22.6	22.5
Other cattle	8.1	8.1	8.0	8.2	8.1	8.0	7.9	7.8	7.6	7.6
Swine	4.5	4.5	4.5	4.5	4.4	4.4	4.3	4.3	4.3	4.2
Sheep	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Goats	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Horses	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Poultry	0.032	0.032	0.032	0.034	0.035	0.035	0.035	0.036	0.036	0.036
[kg place^{-1} a^{-1}]	**2010**	**2011**	**2012**	**2013**						
Dairy cattle	22.1	21.5	21.2	21.2						
Other cattle	7.4	7.2	7.1	7.1						
Swine	4.1	4.1	4.1	4.1						
Sheep	0.21	0.21	0.21	0.21						
Goats	0.22	0.22	0.22	0.22						
Horses	2.6	2.6	2.6	2.6						
Poultry	0.037	0.035	0.034	0.033						

[86] IPCC gives *MCF* in percent (of B_o), the more significant units m^3 m^{-3} are used in the German inventory.

5.3.2.2.3 Emissions (CRF 3.B, CH_4)

Table 215 shows the calculated total CH_4 emissions from manure management.

Table 215: CH_4 emissions from manure management (3.B(a))

[Gg a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	322.94	288.23	285.17	281.83	295.09	291.48	293.06	288.84	294.36	294.02
[Gg a^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
	286.69	289.99	282.83	283.81	275.06	274.94	266.66	265.49	265.15	264.58
[Gg a^{-1}]	**2010**	**2011**	**2012**	**2013**						
	254.31	250.53	251.88	253.74						

Between 1990 and 1993, the emissions decreased by somewhat more than 41 Gg a^{-1}, from 322.9 to 281.8 Gg a^{-1}. That decrease was followed by an increase to a level of 290 Gg a^{-1}, and then, from 2001 to 2012/2013, the emissions decreased by about 36 Gg a^{-1}. Overall, emissions decreased by about 69 Gg a^{-1} from 1990 through 2013. The progression over time is tied largely to the development of animal numbers (cf. Chapter 5.1.3.2), with the effects of such trends modified via emissions-increasing growth in yields (cf. Chapter 5.1.3.2.4) and via increasing emissions reductions as a result of manure digestion; cf.

Table 217 below. The total reduction in the area of manure management amounts to 21.4 % between 1990 and 2013.

Table 216 shows the emissions contributions of dairy cattle, other cattle and swine. These animal categories account for 98.3 % (1990) to 97.1 % (2013) of emissions from the area of manure management. The ratio between the emissions of cattle husbandry and swine husbandry is 2:1 for 1990 and 1.6:1 for 2013.

Table 216: CH_4 emissions from manure management, for dairy cattle, other cattle and swine (3.B(a))

[Gg a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy cattle	105.9	96.5	94.0	93.5	111.5	111.1	111.4	108.1	106.7	106.0
Other cattle	104.1	93.1	90.1	88.2	86.0	85.3	83.8	81.0	80.6	81.9
Swine	107.4	93.1	95.8	94.7	92.0	89.3	92.0	94.1	101.5	100.6
[Gg a^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Dairy cattle	102.5	104.0	101.9	101.8	100.2	98.9	94.5	93.5	95.4	94.5
Other cattle	80.3	81.5	76.0	75.9	72.1	70.0	68.3	67.0	66.9	66.1
Swine	98.2	98.7	99.0	99.9	96.5	99.8	97.5	98.4	96.4	97.6
[Gg a^{-1}]	**2010**	**2011**	**2012**	**2013**						
Dairy cattle	92.4	90.2	88.7	90.4						
Other cattle	63.6	59.9	59.0	59.8						
Swine	91.9	93.7	97.1	96.1						

The CH_4-emissions reductions achieved via manure digestion are shown in

Table 217. Without digestion, the so-saved emissions would have been emitted in addition to the quantities shown in Table 215. Such findings lead to the additional time series, shown in

Table 217, of the reductions – expressed as percentages – achieved via digestion.

Table 217: Absolute and percentage changes in CH_4 emissions as a result of manure digestion, in comparison to a situation with no digestion and storage of digestion residues

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
[Gg a^{-1}]	0.01	0.02	0.03	0.03	0.04	0.10	0.17	0.22	0.49	0.56
[%]	0.00	0.01	0.01	0.01	0.01	0.04	0.06	0.07	0.17	0.19
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
[Gg a^{-1}]	0.89	1.26	1.83	2.18	2.84	6.50	9.50	13.48	16.42	20.43
[%]	0.31	0.43	0.64	0.76	1.02	2.31	3.44	4.83	5.83	7.17
	2010	**2011**	**2012**	**2013**						
[Gg a^{-1}]	25.91	31.67	35.65	36.22						
[%]	9.24	11.22	12.40	12.49						

5.3.2.3 Uncertainties and time-series consistency (3.B, CH_4)

With regard to the uncertainties in the area of methane emissions from manure management, the reader's attention is called to Table 204 in Chapter 5.1.6 (total uncertainty of the German GHG inventory).

All emissions time series are consistent, since they were calculated with the same method for all years of the report period, and since the input data are also consistent and all data gaps have been filled in.

5.3.2.4 Category-specific quality assurance / control and verification (3.B, CH_4)

With regard to quality control and quality assurance, we refer to Chapter 5.1.7.

In the framework of verification, the results and input data obtained for 2012 were compared with the 2012 values of neighbouring countries and of the UK (2014 Submission for 2012, UNFCCC 2014).

As Table 218 shows, Germany's national mean figure for the CH_4 emission factor referenced to animal place (i.e. the implied emission factor (IEF)), for management of dairy cattle manure, lies within the lower part of the range. The German VS-excretions figure also lies at the lower end of the overall range (and is comparable to that of France). Higher CH_4 IEFs are seen in Denmark, France, the Netherlands, Switzerland and the UK, while those of Austria and Poland are significantly lower than that of Germany. That said, it must be noted that the CH_4-IEF values of the various European countries are only conditionally comparable, since they have been obtained from very different data for VS excretions, frequencies of slurry systems and methane conversion factors *MCF*. In addition, it must be noted that the German IEF includes the emissions-reducing effects of manure digestion. (The German values for the numbers of slurry systems, and for the average MCF of slurry systems, refer solely to slurry systems without digestion.) The MCF values of the various countries are comparable only to a limited degree, since the figures in Table 218 – at least for France, Switzerland and the UK – are still based on the old guidelines (IPCC, 1996b, 2000).

As Table 219 shows, in the other cattle category, the German IEF, at 7.09 kg $place^{-1}$ a^{-1}, is in the middle of the large span between 2.81 kg $place^{-1}$ a^{-1} (Belgium) and 15.01 kg $place^{-1}$ a^{-1} (UK), while the German figure for VS excretions, at 1.37 kg $place^{-1}$ d^{-1}, very clearly lies within the lower section of the range formed by neighbouring countries (from 1.23 kg $place^{-1}$ d^{-1} in the Netherlands to 2.70 kg $place^{-1}$ d^{-1} in Denmark). The correlation shown in Table 219 between IEF and VS excretions is very weak. This is due to differences in the percentage numbers for the various manure management systems (i.e. commonness of the systems) and in the systems' methane conversion factors *MCF*. For added clarity, Table 219 presents the pertinent data for slurry systems. The comparability of the MCF values is limited, for the same reasons adduced for the dairy cattle category.

For swine – cf. Table 220 – Germany's value for VS excretions, at 0.30 kg place^{-1} d^{-1}, is higher than the average (0.26 kg place^{-1} d^{-1}) for all countries that have not used the IPCC (1996b) VS default value of 0.50 kg place^{-1} d^{-1}, a value which is no longer valid for the current submission. At the same time, the German VS-excretions value is lower than the average VS-excretions figure (0.31 kg place^{-1} d^{-1}) that results from the IPCC (2006) default values for swine. The IEF values are not comparable, since not all of the values – including both VS-excretions values and MCF values – are based on the currently valid IPCC (2006) guidelines.

Table 218: CH_4 emissions from manure storage in the dairy cattle category, in various countries – a comparison of Implied Emission Factors (*IEF*) and important emissions-relevant parameters for the year 2012

	IEF_{CH4} [kg place^{-1} a^{-1}]	**VS excretions** [kg place^{-1} d^{-1}]	**Use of slurry systems** [%]	**Mean *MCF* for slurry systems** [%]
Austria	9.16	4.30	32.20	8.72
Belgium	17.45	4.15	11.35	19.00
Czech Republic	19.95	k. A.	27.00	k. A.
Denmark	33.60	6.22	88.49	0.10
France [a]	39.80	4.09	40.79	39.00
Germany	**21.16**	**4.01**	**55.49** [b]	**15.173** [b]
Netherlands	43.09	4.56	90.38	17.00
Poland	13.36	4.63	10.53	39.00
Switzerland	26.04	6.21	68.22	10.00
UK	42.90	3.57	41.00	39.00
IPCC (1996b)-3-4.13, 4.43, Western Europe, cool region	14	5.1	40	10
IPCC(2000)-4.36				39.00
IPCC (2006)-10.38, 10.77, Western Europe, cool region	21 through 23 [c]	5.1	35.7	17 through 19 [c]

[a] France: Only temperate zone; frequency of slurry systems calculated from original data

[b] Germany: Only slurry systems with no slurry digestion

[c] Range for the systems and/or temperatures occurring in Germany

Source: Germany: 2015 Submission; other countries: UNFCCC 2014; k.A.: no data (keine Angabe)

Table 219: CH_4 emissions from manure storage in the other cattle category, in various countries – a comparison of Implied Emission Factors (*IEF*) and important emissions-relevant parameters for the year 2012

	IEF_{CH4} [kg place^{-1} a^{-1} CH_4]	**VS excretions** [kg place^{-1} d^{-1}]	**Use of slurry systems [%]**	**Mean *MCF* for slurry systems [%]**
Austria	4.11	1.93	24.45	8.46
Belgium	2.81	1.48	4.03	19.00
Czech Republic	8.65	NA	52.00	NA
Denmark	9.19	2.70	31.06	0.10
France [a]	8.52	1.99	29.03	39.00
Germany	**7.09**	**1.37**	32.82 [b]	15.31 [b]
Netherlands	9.14	1.23	81.71	15.84
Poland	2.24	1.84	50.63	39.00
Switzerland	5.15	2.03	46.85	10.00
UK	15.01	2.29	4.24	39.00
IPCC (1996b)-3-4.13, 4.43, Western Europe, cool region	6	2.7	50	10
IPCC(2000)-4.36				39.00
IPCC (2006)-10.38, 10.77, Western Europe, cool region	6 through 7 [c]	2.6	25.2	17 through 19 [c]

[a] France: Only temperate zone; frequency of slurry systems calculated from original data

[b] Germany: Only slurry systems with no slurry digestion [c] Range for the systems and/or temperatures occurring in Germany

[c] Range for the systems and/or temperatures occurring in Germany

Source: Germany: 2015 Submission; other countries: UNFCCC 2014; k.A.: no data (keine Angabe)

Table 220: CH_4 emissions from storage of manure from swine, in various countries – a comparison of Implied Emission Factors (*IEF*) and important emissions-relevant parameters for the year 2012

	IEF_{CH4} [kg place^{-1} a^{-1} CH_4]	**VS excretions** [kg place^{-1} d^{-1}]	**Use of slurry systems [%]**	**Mean *MCF* for slurry systems [%]**
Austria	1.17	0.27	75.24	3.39
Belgium	7.73	0.35	6.35	19.00
Czech Republic	3.00	k. A.	76.00	k. A.
Denmark	2.30	0.20	97.56	10.00
France [a]	12.85	0.32	92.32	39.00
Germany	**4.10**	**0.30**	**83.12**	**22.11**
Netherlands	2.95	0.16	100.00	39.00
Poland	5.63	0.50	24.32	39.00
Switzerland	5.48	0.50	99.60	10.00
UK	19.02	0.50	38.12	39.00
IPCC (1996b)-3-4.13, 4.42, 4.46, Western Europe, cool region	3	0.5	“pit>1month”:73%	10
IPCC(2000)-4.36				39.00
IPCC (2006)-10.80, 10.81, Western Europe, cool region	Sows, boars: 9 through 10[b] Other: 6	Sows, boars: 0.46 Other: 0.30	“pit>1month”: 70%	17 through 19 [c]

[a] France: Only temperate zone; frequency of slurry systems calculated from original data

[b] Germany: Only slurry systems with no slurry digestion [c] Range for the systems and/or temperatures occurring in Germany

[c] Range for the systems and/or temperatures occurring in Germany

Source: Germany: 2015 Submission; other countries: UNFCCC 2014; k.A.: no data (keine Angabe)

Table 221 shows, for poultry, the average IEF, the average VS excretions and – as an indicator for energy requirements, and thus for feed intake and excretions – the average animal weight. The IEF values listed in Table 221 for France, Poland, Switzerland and the UK include default VS excretions figures pursuant to IPCC (1996b), and thus they are not suited for this international comparisons. The IEF values of Austria and the Czech Republic are at about the same level as that of France. They do not include information about VS excretions, however. Presumably, the IEFs of Austria and the Czech Republic are based on the default VS-excretions figure pursuant to IPCC (1996b), and thus cannot be included in relevant comparisons. Denmark's VS-excretions figure is an order of magnitude smaller than the German VS-excretions figure, even though the animal weight given by Denmark is higher than that listed by Germany. The Danish figure is thus considered to be an outlier. The only countries remaining that are suitable for comparison are Belgium and the Netherlands. Germany's VS-excretions value, 0.024 kg place^{-1} d^{-1}, is about the same as Belgium's value, 0.026 kg place^{-1} d^{-1}. The two countries' IEF values and average animal weights lend themselves well to comparison. While the Netherlands' VS-excretions value is considerably lower than Germany's, its IEF is also lower, by a similar amount, than Germany's IEF.

Table 221: CH_4 emissions from manure storage in the poultry category, in various countries – a comparison of Implied Emission Factors (*IEF*) and important emissions-relevant parameters for the year 2012

	IEF_{CH4} [kg place^{-1} a^{-1} CH_4]	**VS excretions [kg place^{-1} d^{-1}]**	**Mean animal weight [kg animal^{-1}]**
Austria	0.073	k. A.	k. A.
Belgium	0.037	0.026	1.59
Czech Republic	0.078	k. A.	k. A.
Denmark	0.026	0.003	2.00
France	0.079	0.100	k. A.
Germany	**0.034**	**0.025**	**1.72**
Netherlands	0.020	0.015	k. A.
Poland	0.078	0.100	1.10
Switzerland	0.116	0.100	k. A.
UK	0.116	0.100	k. A.
IPCC (1996b)-3-4.47, cool region, developed countries	0.078	0.10	1.10
IPCC(2000)-4.36			
IPCC (2006)-10.82, We. Eur., cool reg., dev. countries	0.02 to 0.09	0.01 to 0.07	0.9 to 6.8

Source: Germany: 2015 Submission; other countries: UNFCCC 2014; k.A.: no data (keine Angabe)

5.3.2.5 Category-specific recalculations (3.B, CH_4)

Table 222 and Table 223 show the VS excretions and emission factors for dairy cattle, other cattle swine and poultry. The differences between the 2014 NIR and the 2015 NIR are due primarily to the following changes in yield-determining data and calculation methods:

- **Dairy cattle:** The slight changes in VS excretions – and, thus, in the emission factor – are due to changes in feed composition. Those changes, in turn, result from changes in yield data (animal weight, calf birth weight, milk production) and from changes in the division of populations among dairy cattle with mixed diet and grass based diet (cf. Chapter 5.1.3.2.4).
- **Other cattle:** The reductions in the VS excretions and the emission factor result from changes in the relevant model (a shift of the age limit separating calves from heifers / male beef cattle) and from updating of the yield data for heifers (animal weights, calf birth weights) (cf. Chapter 5.1.3.2.4).

- **Swine:** The increases in the VS excretions and the emission factor result directly from elimination of vacancy periods for the weaners and fattening pigs categories (cf. Chapter 5.1.3.2.4).
- **Poultry:** On the one hand, the changes in the VS excretions and in the emission factor, with respect to the 2014 NIR, are due to the correction in vacancy periods and to the use of the new model for broilers (cf. Chapter 5.1.3.2.4). On the other hand, a daily VS-excretions figure of 0.055 kg pl^{-1} d^{-1} has been back calculated for geese from the pertinent Tier 1 emissions figure. This was done to compensate for the lack of a relevant IPCC default value (RÖSEMANN et al., 2015, Chapter 9.9.1.3). The resulting value is higher than the average VS value for poultry.
- **Manure digestion (including pre-storage and storage of digestion residues):** The pertinent methods have been improved with respect to the procedure used for the 2014 NIR (now with differentiation of substrates into the categories cattle slurry, cattle solid manure, swine slurry, poultry manure; with pre-storage of substrate; and with inclusion of CH_4 emissions via leaks from gas-tight storage systems). The activity data have been updated (with regard to substrate input and frequency of gas-tight storage of digestion residues). For details, cf. Chapter 5.1.3.6.5.

Table 222: Comparison of VS excretions as reported in the NIR 2015 and as reported in the NIR 2014 (3.B(a))

[kg place^{-1} d^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy cattle, 2015	3.47	3.50	3.57	3.61	3.61	3.63	3.67	3.68	3.72	3.75
Dairy cattle, 2014	3.47	3.50	3.57	3.62	3.62	3.64	3.68	3.69	3.74	3.77
Other cattle, 2015	1.37	1.37	1.39	1.40	1.40	1.40	1.40	1.41	1.41	1.43
Other cattle, 2014	1.43	1.42	1.45	1.47	1.45	1.46	1.46	1.46	1.47	1.5
Swine, 2015	0.264	0.274	0.276	0.276	0.277	0.278	0.280	0.281	0.283	0.285
Swine, 2014	0.239	0.246	0.248	0.249	0.251	0.252	0.255	0.255	0.258	0.256
Poultry, 2015	0.0226	0.0229	0.0228	0.0224	0.0221	0.0222	0.0219	0.0221	0.0222	0.0221
Poultry, 2014	0.0218	0.022	0.022	0.0215	0.0212	0.0211	0.0209	0.021	0.0213	0.0211
[kg place^{-1} d^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Dairy cattle, 2015	3.78	3.83	3.84	3.87	3.87	3.90	3.91	3.94	3.90	3.94
Dairy cattle, 2014	3.8	3.85	3.86	3.89	3.89	3.92	3.93	3.96	3.93	3.95
Other cattle, 2015	1.43	1.43	1.41	1.41	1.40	1.40	1.40	1.40	1.39	1.39
Other cattle, 2014	1.49	1.50	1.48	1.48	1.47	1.47	1.47	1.47	1.46	1.47
Swine, 2015	0.284	0.287	0.285	0.286	0.286	0.288	0.289	0.289	0.290	0.294
Swine, 2014	0.256	0.26	0.26	0.259	0.261	0.26	0.261	0.262	0.261	0.261
Poultry, 2015	0.0231	0.0234	0.0234	0.0245	0.0257	0.0259	0.0259	0.0265	0.0263	0.0267
Poultry, 2014	0.0222	0.0226	0.0225	0.0236	0.0249	0.0252	0.025	0.0258	0.0255	0.0258
[kg place^{-1} d^{-1}]	**2010**	**2011**	**2012**	**2013**						
Dairy cattle, 2015	3.97	3.99	4.01	4.01						
Dairy cattle, 2014	3.98	4.00	4.01							
Other cattle, 2015	1.39	1.38	1.37	1.38						
Other cattle, 2014	1.47	1.46	1.45							
Swine, 2015	0.293	0.295	0.297	0.298						
Swine, 2014	0.261	0.257	0.257							
Poultry, 2015	0.0271	0.0263	0.0254	0.0245						
Poultry, 2014	0.0265	0.0268	0.0272							

Table 223: Comparison of the animal-place-based CH_4 emission factors, as reported in the NIR 2015 and as reported in the NIR 2014, for manure management (3.B(a))

[kg place^{-1} a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy cattle, 2015	16.7	17.1	17.5	17.6	21.2	21.3	21.5	21.5	22.1	22.3
Dairy cattle, 2014	16.7	17.1	17.5	17.7	21.2	21.3	21.5	21.6	22.1	22.3
Other cattle, 2015	7.93	8.10	8.31	8.32	8.04	8.01	7.94	7.94	7.97	8.09
Other cattle, 2014	8.28	8.42	8.69	8.72	8.37	8.38	8.32	8.3	8.34	8.51
Swine, 2015	4.05	4.20	4.23	4.26	4.35	4.38	4.42	4.43	4.51	4.54
Swine, 2014	3.64	3.72	3.77	3.81	3.92	3.95	4.00	3.99	4.09	4.05
Poultry, 2015	0.0316	0.0318	0.0317	0.0311	0.0306	0.0307	0.0303	0.0305	0.0307	0.0304
Poultry, 2014	0.0307	0.0309	0.0308	0.0301	0.0296	0.0295	0.0291	0.0293	0.0296	0.0293
[kg pl^{-1} a^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Dairy cattle, 2015	22.4	22.9	23.0	23.3	23.4	23.3	23.2	23.0	22.6	22.5
Dairy cattle, 2014	22.5	22.9	23.1	23.3	23.4	23.2	22.8	22.4	22	21.5
Other cattle, 2015	8.05	8.11	7.95	8.19	8.09	7.96	7.88	7.78	7.64	7.56
Other cattle, 2014	8.28	8.42	8.69	8.72	8.37	8.38	8.32	8.3	8.34	8.51
Swine, 2015	4.51	4.53	4.48	4.47	4.44	4.39	4.35	4.28	4.25	4.24
Swine, 2014	3.64	3.72	3.77	3.81	3.92	3.95	4.00	3.99	4.09	4.05
Poultry, 2015	0.0317	0.0322	0.0320	0.0335	0.0351	0.0353	0.0353	0.0361	0.0358	0.0361
Poultry, 2014	0.0307	0.0309	0.0308	0.0301	0.0296	0.0295	0.0291	0.0293	0.0296	0.0293
[kg pl^{-1} a^{-1}]	**2010**	**2011**	**2012**	**2013**						
Dairy cattle, 2015	22.1	21.5	21.2	21.2						
Dairy cattle, 2014	20.9	20.1	19.6							
Other cattle, 2015	7.37	7.18	7.09	7.10						
Other cattle, 2014	8.32	8.28	8.28							
Swine, 2015	4.13	4.11	4.10	4.11						
Swine, 2014	3.45	3.34	3.31							
Poultry, 2015	0.0366	0.0355	0.0342	0.0329						
Poultry, 2014	0.0359	0.0363	0.0367							

The changes in the emission factor, between the 2014 NIR and the 2015 NIR, are even more pronounced in the emissions figures, as a result of multiplication by animal-place figures. In the sum over all animals, the emissions are higher in the 2015 NIR than they are in the 2014 NIR, with an increasing trend toward the end of the time series: The discrepancies range from 6.3 Gg a^{-1} (1990) to 16.0 Gg a^{-1} (2012).

Table 224: Comparison of CH_4 emissions from manure management as reported in the NIR 2015 and as reported in the NIR 2014 (3.B(a))

[Gg a^{-1} CH_4]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
All animals, 2015	**322.9**	**288.2**	**285.2**	**281.8**	**295.1**	**291.5**	**293.1**	**288.8**	**294.4**	**294.0**
All animals, 2014	**316.6**	**281.4**	**278.7**	**276.3**	**289.7**	**287.1**	**288.7**	**283.5**	**289.1**	**287.8**
Dairy cattle, 2015	105.9	96.5	94.0	93.5	111.5	111.1	111.4	108.1	106.7	106.0
Dairy cattle, 2014	105.8	96.5	94.0	93.7	111.6	111.4	111.8	108.4	107	106.4
Other cattle, 2015	104.1	93.1	90.1	88.2	86.0	85.3	83.8	81.0	80.6	81.9
Other cattle, 2014	108.7	96.8	94.2	92.4	89.5	89.3	87.9	84.7	84.3	86.3
Swine, 2015	107.4	93.1	95.8	94.7	92.0	89.3	92.0	94.1	101.5	100.6
Swine, 2014	96.4	82.5	85.2	84.7	82.9	80.6	83.2	84.8	92.1	89.7
Poultry, 2015	3.60	3.46	3.29	3.32	3.37	3.42	3.41	3.49	3.57	3.60
Poultry, 2014	3.50	3.36	3.19	3.22	3.26	3.29	3.28	3.35	3.44	3.46
[Gg a^{-1} CH_4]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
All animals, 2015	**286.7**	**290.0**	**282.8**	**283.8**	**275.1**	**274.9**	**266.7**	**265.5**	**265.1**	**264.6**
All animals, 2014	**281.1**	**284.8**	**278.0**	**277.1**	**269.3**	**267.6**	**259.1**	**256.9**	**255.8**	**252.8**
Dairy cattle, 2015	102.5	104.0	101.9	101.8	100.2	98.9	94.5	93.5	95.4	94.5
Dairy cattle, 2014	102.8	104.3	102.1	101.9	100.1	98.1	93.1	91	92.6	90.3
Other cattle, 2015	80.3	81.5	76.0	75.9	72.1	70.0	68.3	67.0	66.9	66.1
Other cattle, 2014	84.7	86	80.5	79.5	75.6	74.7	73.4	72.9	73.3	73.2
Swine, 2015	98.2	98.7	99.0	99.9	96.5	99.8	97.5	98.4	96.4	97.6
Swine, 2014	87.8	88.6	89.6	89.5	87.3	88.7	86.3	86.4	83.4	82.8
Poultry, 2015	3.81	3.92	3.93	4.14	4.29	4.26	4.37	4.58	4.57	4.63
Poultry, 2014	3.69	3.80	3.79	3.99	4.15	4.13	4.23	4.46	4.43	4.50

[Gg a^{-1} CH_4]	2010	2011	2012	2013
All animals, 2015	**254.3**	**250.5**	**251.9**	**253.7**
All animals, 2014	**242.5**	**235.8**	**235.9**	
Dairy cattle, 2015	92.4	90.2	88.7	90.4
Dairy cattle, 2014	87.5	84.1	82.2	
Other cattle, 2015	63.6	59.9	59.0	59.8
Other cattle, 2014	71.8	69.1	68.8	
Swine, 2015	91.9	93.7	97.1	96.1
Swine, 2014	76.8	76.1	78.3	
Poultry, 2015	4.72	5.15	5.51	5.84
Poultry, 2014	4.62	4.80	4.86	

5.3.2.6 Planned improvements (category-specific) (3.B, CH_4)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

5.3.3 NMVOC emissions from manure management

5.3.3.1 Category description (NMVOC)

Cf. Chapter 5.3.1.

5.3.3.2 Methodological aspects (NMVOC)

5.3.3.2.1 Methods (NMVOC)

The IPCC does not provide any method for calculating NMVOC emissions from manure-management. EMEP (2013) provides methods and the relevant parameters. Germany uses the Tier 1 method (EMEP, 2013-3B-13 ff). The calculation is carried out separately for the various animal categories.

Equation 14: Tier 1 method for calculation of annual NMVOC emissions from manure management

$$E_{\text{NMVOC, MM, i}} = n_{\text{i}} \cdot EF_{\text{NMVOC, MM, i}}$$

Where

$E_{\text{NMVOC, MM, i}}$	NMVOC emissions from manure management for animal category i (in kg a^{-1})
n_i	Number of animal places in animal category i (in places)
$EF_{\text{NMVOC, MM, i}}$	NMVOC emission factor for animal category i (in kg $place^{-1}$ a^{-1})

5.3.3.2.2 Emission factors (NMVOC)

EMEP (2013)-3B-16, Table 3.3, provides (except for swine) different emission factors for feeding with and without silage. For swine, it lists only emission factors for feeding without silage. For cattle and horses, the German inventory applies the emission factors for feeding with silage; for sheep and goats, it uses the factors for feeding without silage.

In a conservative approach, the emission factor for sows is used for boars, and the factor for fattening pigs is used for weaners.

The emission factor for sheep listed in EMEP (2013) has been interpreted as applying to mature sheep. Pursuant to Rösemann et al. (2015), the emission factor for lambs is to be set at 40 % of the emission factor for mature sheep.

The emission factor for horses listed in EMEP (2013) has been interpreted as applying to heavy horses. For light horses and ponies, the emission factor given in EMEP (2013) for mules and asses has been used.

Due to the similarity in the applicable housing systems, the emission factor for broilers has been used for pullets.

Table 225 presents a list of the emission factors used in the inventory.

Table 225: NMVOC emission factors pursuant to EMEP (2013) that are used in the inventory

[kg place^{-1} a^{-1}]	EF_{NMVOC}
Dairy cattle	17.937
Other cattle	8.902
Sows, boars	1.704
Fattening pigs, weaners	0.551
Mature sheep	0.169
Lambs	0.068
Goats	0.542
Heavy horses	7.781
Light horses and ponies	3.018
Laying hens	0.165
Broilers, pullets	0.108
Geese, ducks and turkeys	0.489

5.3.3.2.3 Emissions (NMVOC)

Table 226 lists the NMVOC emissions from manure management that are to be reported under CRF 3s1. In keeping with the Tier 1 method used (cf. Chapter 5.3.3.2.1), the time series directly reflect the trends in numbers of animals (cf. Chapter 5.1.3.2.3).

The total emissions decreased by 26.9 %, from 271.4 Gg a^{-1} in 1990 to 198.4 Gg a^{-1} in 2013. The cattle contribution to the total emissions decreased from 85.1 % in 1990 to 76.4 % in 2013, while the poultry contribution increased from 6.8 % to 14.2 %. With this result, the contribution of all other animal categories taken together has remained at a low level (1990: 8.2 %; 2013: 9.4 %).

Table 226: NMVOC emissions from manure management

[Gg a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total	271.4	240.5	229.5	226.5	226.7	225.6	224.9	218.9	215.3	214.1
Dairy cattle	114.0	101.0	96.2	95.1	94.6	93.8	93.2	90.2	86.7	85.5
Other cattle	116.9	102.4	96.5	94.3	95.2	94.9	94.0	90.8	90.0	90.2
Swine	18.4	15.7	16.0	15.6	14.8	14.2	14.5	14.8	15.5	15.4
Sheep	0.43	0.42	0.39	0.39	0.38	0.39	0.39	0.38	0.37	0.36
Goats	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.07	0.07
Horses	3.2	3.4	3.5	3.7	3.9	4.1	4.3	3.9	3.6	3.3
Poultry	18.3	17.6	16.8	17.3	17.8	18.1	18.4	18.7	19.0	19.3
[Gg a^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Total	209.3	210.4	204.3	201.2	195.6	193.9	190.4	190.8	194.1	193.8
Dairy cattle	82.0	81.6	79.4	78.4	76.9	76.0	73.2	73.0	75.7	75.4
Dairy cattle	88.7	89.5	85.1	82.6	79.3	78.3	77.2	76.7	77.9	77.8
Other cattle	15.0	15.1	15.2	15.4	14.9	15.5	15.3	15.6	15.3	15.4
Swine	0.36	0.37	0.36	0.36	0.36	0.35	0.34	0.33	0.32	0.31
Sheep	0.08	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.12
Goats	3.3	3.4	3.5	3.6	3.5	3.4	3.5	3.7	3.5	3.3
Horses	19.8	20.3	20.6	20.9	20.6	20.3	20.8	21.3	21.4	21.5

[Gg a^{-1}]	2010	2011	2012	2013
Total	191.7	191.7	194.1	198.4
Dairy cattle	75.0	75.2	75.2	76.5
Dairy cattle	76.8	74.2	74.1	74.9
Other cattle	14.9	15.1	15.5	15.3
Swine	0.30	0.26	0.26	0.25
Sheep	0.08	0.08	0.07	0.07
Goats	3.1	3.1	3.1	3.1
Horses	21.6	23.8	26.0	28.2

5.3.3.3 Uncertainties and time-series consistency (NMVOC)

Pursuant to EMEP(2013)-3B-33, the calculation procedure must be considered solely a first approach to the task of estimating NMVOC emissions from animal husbandry; the pertinent uncertainty is considered very high. EMEP (2013) does not carry out relevant quantification.

5.3.3.4 Category-specific quality assurance / control and verification (NMVOC)

With regard to quality control and quality assurance, we refer to Chapter 5.1.7.

5.3.3.5 Category-specific recalculations (NMVOC)

No recalculations have been carried out, since the 2014 NIR did not report NMVOC emissions.

5.3.3.6 Planned improvements (category-specific) (NMVOC)

No improvements are planned at present.

5.3.4 Direct N_2O and NO emissions from manure management (3.B, N_2O & NO)

5.3.4.1 Category description (3.B, N_2O_{direct} & NO)

Cf. Chapter 5.3.1.

5.3.4.2 Methodological issues (3.B, N_2O_{direct} & NO)

5.3.4.2.1 Methods (3.B, N_2O_{direct} & NO)

N_2O emissions from manure management are calculated separately for all animal categories, taking account of the management systems in use (and including manure digestion; cf. Chapter 5.1.3.6.5):

Equation 15: Calculation of N_2O emissions from manure management

$$E_{\mathrm{N2O\text{-}N}} = \sum_{\mathrm{i,j}} [(N_{\mathrm{excr,\,i}} + N_{\mathrm{straw,\,i,\,j}}) \cdot MS_{\mathrm{i,\,j}}] \cdot EF_{\mathrm{N2O\text{-}N,\,j}}$$

where:

$E_{N2O\text{-}N}$	Total N_2O-N emissions from manure management (kg a^{-1} N_2O-N)
$N_{excr,\,i}$	Total N excretions of animal category i (kg a^{-1} N)
$N_{straw,\,i,\,j}$	N input via bedding material, for animal category i and manure-management system j (kg a^{-1} N)
$MS_{i,\,j}$	Relative share of manure management system j in animal category i (place place^{-1})
$EF_{N2O\text{-}N,\,j}$	N_2O-N emission factor for manure management system j (kg kg^{-1} N_2O-N)

With regard to total N excretions and total N inputs via bedding material, cf. Chapters 5.1.3.4 and 5.1.3.6.2. With regard to the relative frequencies of manure management systems, cf. Chapters 5.1.3.6.1 and 19.3.1.

NO emissions from manure management are calculated using a method similar to that used to calculate the relevant N_2O emissions.

N_2O and NO emissions from manure application and grazing are reported under 3.D.

5.3.4.2.2 Emission factors (3.B, N_2O_{direct} & NO)

For slurry storage, the default emission factors given in IPCC(2006)-10.62 are used where possible (outdoor storage without cover = outdoor storage without natural crust; outdoor storage with natural crust; storage below slatted floor). In a conservative approach, for slurry storage with solid cover, or with artificial floating cover (chips) – both of which are not mentioned in IPCC (2006) – the emission factor for outdoor storage with natural crust is used. For slurry storage under a foil cover, which is also not mentioned in IPCC (2006), it is assumed that the emission factor for outdoor storage without natural crust can be used.

Systems for storage of solid manure are broken down into the categories tied systems / pens allowing free movement (with storage in heaps) and deep bedding. For storage of solid manure from tied systems / loose-housing systems the emission factor derived by VANDRÉ et al. (2013) is used: 0.013 kg N_2O-N (kg N)$^{-1}$. For deep bedding, the IPCC (2006) default value is used: 0.010 kg N_2O-N (kg N)$^{-1}$ (IPCC(2006)-10.63).

The inventory calculations for poultry manure are based on the IPCC (2006) default emission factor: 0.001 kg N_2O-N (kg N)$^{-1}$ (IPCC(2006)-10.63).

Manure digestion, including storage of digestion residues, is treated in IPCC (2006)-10.63 as a separate storage type. The German inventory does not use the IPCC default value for the N_2O emission factor, however, since it calculates the relevant N_2O emissions separately for the various types of manure and digested-manure storage; cf. Chapter 5.1.3.6.5.

Table 227 provides an overview of the N_2O emission factors used in the NIR 2015.

Table 227: Emission factors for emissions of N_2O-N from manure management (in relation to total excreted N and straw-bedding N) (3.B(b))

Manure		Emission factor [kg kg^{-1}]
Slurry	Open tank, without natural crust [a]	0.000
	Solid cover [b]	0.005
	Natural crust [a]	0.005
	Floating cover (chaff) [b]	0.005
	Floating cover (plastic film) [c]	0.000
	Below slatted floor [a]	0.002
Solid manure [d]		0.013
Deep bedding[a]		0.010
Poultry, solid manure or faeces[a]		0.001

[a] Source: IPCC (2006)
[b] Worst-case assumption: Like natural crust, since no information is available.
[c] Assumption: With floating foil covers, no N_2O formation occurs.
[d]Source: VANDRÉ et al. (2013)

IPCC does not give any emission factors for NO. The Tier-1 emission factors given in EMEP (2009)-4B-16 (cf. also EMEP (2013)-3B-15) refer to animal places and thus cannot be used in the GAS-EM inventory model, which, in the framework of the N-flow concept (cf. Chapter 5.1.2.4), requires emission factors that are related to N amounts. At the same time, comparative calculations show that the German total NO emissions from Sector 3.B as calculated with the Tier 1 method pursuant to EMEP (2009) can be reproduced with GAS-EM when the NO-N emission factor oriented to N is smaller than the N_2O-N emission factor by one order of magnitude. For this reason, in the inventory, the NO-N emission factor has been set at a level of 10 % of the N_2O-N emission factor. This approach yields NO emissions that are proportional to the relevant N_2O emissions.

Neither IPCC nor EMEP gives emission factors for N_2 (which must also be taken into account in the N-flow concept; cf. Chapter 5.1.2.4). JARVIS & PAIN (1994) obtained 3:1 as the ratio of N_2 emissions to N_2O-N emissions. Therefore, for purposes of the inventory, it has been assumed that N_2 emission factor is three times as large as the N_2O-N emission factor.

Table 228 shows the time series for the average N_2O-N emission factors for the four manure management systems "slurry-based (without digestion)", "straw-based (without deep bedding and without digestion)", "deep bedding (without digestion)" and "digestion". These emission factors are defined as the ratio of total N_2O-N emissions from a management system to the sum of animal N excretions in the same management system. Under this perspective, the total N_2O emissions of systems with straw bedding also include fractions tied to bedding-N. For this reason, the resulting emission factor for deep bedding that is listed in Table 228 is higher than the factor given in Table 227. The same holds, in principle, for straw-based systems without deep bedding and without digestion, although the effect is not perceived, because the relevant values in Table 228 also include the low emission factor for poultry (cf. Table 227).

Table 228: Average N_2O-N emission factors, by manure management systems (3.B(b))

[kg kg^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Slurry-based [a]	0.00328	0.00343	0.00342	0.00343	0.00383	0.00382	0.00382	0.00380	0.00378	0.00378
Straw-based [b]	0.01055	0.01022	0.01020	0.01022	0.00937	0.00940	0.00943	0.00930	0.00904	0.00904
Deep bedding [a]	0.01173	0.01155	0.01152	0.01153	0.01136	0.01138	0.01139	0.01134	0.01129	0.01128
Digestion	0.00549	0.00543	0.00538	0.00534	0.00515	0.00511	0.00507	0.00502	0.00495	0.00491
[kg kg^{-1}]	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Slurry-based [a]	0.00382	0.00382	0.00382	0.00382	0.00386	0.00385	0.00382	0.00382	0.00379	0.00378
Straw-based [b]	0.00889	0.00891	0.00888	0.00863	0.00846	0.00856	0.00864	0.00862	0.00872	0.00876
Deep bedding [a]	0.01131	0.01133	0.01130	0.01129	0.01127	0.01125	0.01124	0.01124	0.01124	0.01122
Digestion	0.00487	0.00483	0.00479	0.00471	0.00464	0.00457	0.00432	0.00407	0.00382	0.00357
[kg kg^{-1}]	2010	2011	2012	2013						
Slurry-based [a]	0.00381	0.00372	0.00360	0.00353						
Straw-based [b]	0.00869	0.00860	0.00862	0.00863						
Deep bedding [a]	0.01119	0.01115	0.01114	0.01115						
Digestion	0.00332	0.00306	0.00248	0.00248						

[a] Without digestion

[b] Without deep bedding and without digestion

5.3.4.2.3 *Emissions (3.B, N_2O_{direct} & NO)*

Table 229 shows the direct total N_2O emissions from manure management

Between 1990 and 2013, annual emissions from manure management decreased by 27.8 %, from 13.0 Gg N_2O to about 9.6 Gg N_2O. This development reflects the reduction in total N excretions, which is tied to trends in population figures and in feeding (cf. Chapter 5.1.3.4). The sharp emissions decrease seen through 1994, for example, resulted primarily from decreases in livestock populations following German reunification. The shifts, over time, in the relative shares of management systems (cf. Chapters 5.1.3.6.1 and 19.3.1), and the modification, with respect to the 2014 NIR, in calculation of manure digestion (cf. Chapter 5.1.3.6.5), have also had an effect.

Table 229 also shows the breakdown of emissions from manure management in accordance with system categories, while Table 230 shows the N_2O emissions from manure management for the three most important animal categories (dairy cattle, other cattle and swine). Cattle have accounted for the largest shares: 79.3 % in 1990 and 71.1 % in 2013. Cattle and swine together have accounted for 93.1 % (1990) and 90.9 % (2013).

Table 229: Direct N_2O emissions from manure management, total and by system categories (3.B(b))

[Gg a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total, manure management	12.993	11.529	11.323	11.316	10.634	10.636	10.692	10.458	10.237	10.210
Slurry-based [a]	4.628	4.299	4.228	4.184	5.163	5.094	5.119	5.017	5.073	5.053
Straw-based [b]	7.413	6.432	6.224	6.241	4.555	4.588	4.629	4.513	4.215	4.169
Deepbedding [a]	0.951	0.797	0.870	0.890	0.915	0.950	0.937	0.919	0.930	0.966
Digestion	0.000	0.001	0.001	0.002	0.002	0.004	0.007	0.009	0.020	0.023
[Gg a^{-1}]	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total, manure management	10.133	10.330	10.109	10.055	9.856	9.959	9.843	9.940	9.990	10.040
Slurry-based [a]	4.939	4.985	4.851	4.814	4.692	4.635	4.410	4.323	4.216	4.145
Straw-based [b]	4.137	4.236	4.163	3.884	3.821	3.842	3.864	3.919	3.967	3.997
Deepbedding [a]	1.020	1.058	1.022	1.270	1.233	1.251	1.244	1.262	1.309	1.326
Digestion	0.036	0.051	0.073	0.086	0.110	0.232	0.326	0.436	0.497	0.573
[Gg a^{-1}]	2010	2011	2012	2013						
Total, manure management	9.873	9.692	9.553	9.625						
Slurry-based [a]	3.948	3.739	3.598	3.547						
Straw-based [b]	3.943	3.945	4.026	4.129						
Deepbedding [a]	1.310	1.255	1.249	1.262						
Digestion	0.672	0.752	0.680	0.687						

[a] Without digestion

[b] Without deep bedding and without digestion

Table 230: Direct N_2O emissions from manure management for dairy cattle, other cattle and swine (3.B(b))

[Gg a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy cattle	5.29	4.67	4.59	4.63	3.97	3.96	3.99	3.90	3.75	3.75
Other cattle	4.95	4.26	4.09	4.04	4.17	4.20	4.16	4.04	3.99	4.06
Swine	1.84	1.68	1.73	1.69	1.51	1.46	1.49	1.52	1.55	1.53
[Gg a^{-1}]	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Dairy cattle	3.68	3.74	3.66	3.65	3.60	3.61	3.49	3.51	3.52	3.51
Other cattle	4.02	4.10	3.90	3.78	3.66	3.64	3.60	3.58	3.66	3.68
Swine	1.53	1.57	1.62	1.68	1.67	1.78	1.80	1.88	1.87	1.93
[Gg a^{-1}]	2010	2011	2012	2013						
Dairy cattle	3.47	3.44	3.34	3.40						
Other cattle	3.65	3.49	3.42	3.46						
Swine	1.88	1.90	1.92	1.90						

Table 231 shows the absolute and percentage changes in N_2O emissions as a result of manure digestion, in comparison to a situation with no digestion and storage of digestion residues. Negative values denote a digestion-related emissions increase. The primary reason for the increase is that storage of digestion residues, if it is not gas-tight, generates higher N_2O emissions than does conventional storage of manure. What is more, storage of digested poultry slurry tends to produce higher N_2O emissions than does storage of undigested poultry manure. Over the years, the fraction of storage systems with gas-tight storage has been increasing (cf. Chapter 5.1.3.6.5), but bottom-line savings of N_2O emissions do not begin until 2008.

Table 231: Absolute and percentage changes in direct N_2O emissions as a result of manure digestion, in comparison to a situation with no digestion and storage of digestion residues (negative values: emissions increase)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
[Gg a^{-1}]	-0.10	-0.09	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08
[%]	-0.8	-0.8	-0.7	-0.7	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
[Gg a^{-1}]	-0.068	-0.070	-0.069	-0.069	-0.068	-0.084	-0.063	-0.035	0.005	0.059
[%]	-0.7	-0.7	-0.7	-0.7	-0.7	-0.9	-0.6	-0.3	0.0	0.6
	2010	2011	2012	2013						
[Gg a^{-1}]	0.142	0.245	0.435	0.430						
[%]	1.4	2.5	4.4	4.3						

Table 232 shows the total NO emissions from management of manure and of digestion residues. Because the emission factors of NO and N_2O are proportional to each other, the trends for NO are identical to those for N_2O.

Table 232: NO emissions from manure management

[Gg a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	1.772	1.572	1.544	1.543	1.450	1.450	1.458	1.426	1.396	1.392
[Gg a^{-1}]	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	1.382	1.409	1.378	1.371	1.344	1.358	1.342	1.355	1.362	1.369
[Gg a^{-1}]	2010	2011	2012	2013						
	1.346	1.322	1.303	1.313						

5.3.4.3 Uncertainties and time-series consistency (3.B, N_2O_{direct} & NO)

With regard to the uncertainties in the area of N_2O emissions from manure management, the reader's attention is called to Table 204 in Chapter 5.1.6 (total uncertainty of the German GHG inventory).

With regard to uncertainties in the area of N_2O emissions, cf. also RÖSEMANN et al. (2015).

All emissions time series are consistent, since they were calculated with the same method for all years of the report period, and since the input data are also consistent and all data gaps have been filled in.

5.3.4.4 Category-specific quality assurance / control and verification (3.B, N_2O_{direct} & NO)

With regard to quality control and quality assurance, we refer to Chapter 5.1.7.

In the framework of verification, the N excretions from Germany (current report, year 2012) and from neighbouring countries, including the UK (Submission 2014 for the 2012, UNFCCC 2014) were compared; cf. Table 233. The comparison shows that Germany's values for dairy cattle lie in about the middle of the overall range, while its N excretions levels for other cattle are in the lower part of the range.

The N excretions for dairy cattle as calculated in accordance with the specifications of IPCC (2006), like the similarly high values pursuant to EMEP (2013) for central Europe, seem in general to be too low, while the value for other cattle, as calculated pursuant to IPCC (2006), lies in the middle of the range covered by the reported data. The German value for other cattle tends to be at about the level of the EMEP (2013) value.

The N excretions of swine as reported by Germany, along with the corresponding values of Poland and the UK, lie within the upper range of the data reported by neighbouring countries. Since the compositions of swine populations in other countries are not reported, the comparability of the values is highly limited. In the fattening pigs category, the value calculated pursuant to IPCC (2006) is clearly too low, while the EMEP (2013) value fits well with the circumstances prevailing in Germany.

In the poultry category, Germany has the highest N excretions of all countries compared. As is the case in the swine category, direct comparisons are hampered by a lack of data regarding the composition of the total populations in the various countries.

Table 233: N excretions per animal place, for dairy cattle, other cattle, swine and poultry of various countries, for the year 2012

	Dairy cattle [kg place^{-1} a^{-1}]	Other cattle [kg place^{-1} a^{-1}]	Swine [kg place^{-1} a^{-1}]	Poultry [kg place^{-1} a^{-1}]
Austria	100.26	46.25	9.48	0.55
Belgium	118.12	54.68	9.90	0.60
Czech Republic	135.78	69.10	20.00	0.60
Denmark	138.03	43.39	8.01	0.54
France	115.16	57.63	6.95	0.48
Germany	**117.63**	**42.94**	**12.90**	**0.74**
Netherlands	122.30 [a]	44.78 [a]	8.58	0.60
Poland	86.70	57.86	13.56	0.35
Switzerland	108.17 [a]	37.96 [a]	9.15	0.53
UK	122.56	53.74	10.41	0.58
IPCC (2006)-10.59, 10.72, 10.78,10.80, 10.81, 10.82	105.1 [b]	50.6 [b]	9.3 / 30.4 [b, d]	0.53 [b, c]
EMEP (2013)- 3B-27	105	41	12.1 / 34.5 [d]	0.36 to 1.64

Source: Germany: Submission 2015; other countries: UNFCCC 2014

a) Calculated from reported original data

b Calculated pursuant to IPCC (2006), with the IPCC's standard values for weight and N excretions and, in the case of poultry, with the national animal counts in the various poultry sub-categories (Submission 2015)

c Assumptions for lacking values: Weight of geese = 1/2 standard weight of turkeys (IPCC 2006); N excretions of geese = standard N excretions of turkeys (IPCC 2006); weight of pullets = 1/2 standard weight of laying hens (IPCC 2006); N excretions of pullets = standard N excretions of laying hens (IPCC 2006)

d IPCC (2006): Sows and boars: 30.4, other: 9.3; EMEP (2013): Sows: 34.5, fattening pigs: 12.1

The N_2O emission factors and emissions cannot be compared with the corresponding data of neighbouring countries, since the most recent available data of such other countries are still based on IPCC (1996b), while the German results have been calculated on the basis of IPCC (2006).

5.3.4.5 Category-specific recalculations (3.B, N_2O_{direct} & NO)

Table 234 presents the N_2O emissions in Sector 3.B in comparison with the relevant results reported in the 2014 NIR.

Table 234: Comparison of total N_2O emissions from manure management – as calculated for the 2014 NIR and as calculated for the 2015 NIR

[Gg a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
2015	12.993	11.529	11.323	11.316	10.634	10.636	10.692	10.458	10.237	10.210
2014	12.538	11.119	10.944	10.955	10.237	10.259	10.311	10.051	9.843	9.777
[Gg a^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
2015	10.133	10.330	10.109	10.055	9.856	9.959	9.843	9.940	9.990	10.040
2014	9.731	9.936	9.702	9.637	9.457	9.481	9.323	9.367	9.405	9.400
[Gg a^{-1}]	**2010**	**2011**	**2012**	**2013**						
2015	9.873	9.692	9.553	9.625						
2014	9.228	9.017	8.994							

Throughout the entire time series, the N_2O emissions are higher than as reported in the 2014 NIR. This is due to the reasons presented in Chapter 5.3.4.2.3 with regard to manure management (including manure digestion). For the same reasons, the N excretions data have changed; cf. Table 235.

Table 235: Comparison of total N excretions, as calculated for the NIR 2015 and as calculated for the NIR 2014 (summary of Table 169 in Chapter 5.1.3.4)

[Gg a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
N excretions, 2015	1610.9	1437.2	1414.0	1408.1	1387.9	1383.7	1392.4	1369.7	1372.5	1367.8
N excretions, 2014	1590.2	1416.1	1396.2	1393.3	1369.6	1369.1	1377.8	1349.4	1352.8	1343.9
[Gg a^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
N excretions, 2015	1344.9	1363.2	1327.4	1322.3	1292.9	1298.4	1276.3	1287.9	1292.7	1303.2
N excretions, 2014	1324.1	1343.7	1307.2	1297.3	1271.6	1274.9	1251.7	1265.6	1270.0	1276.6
[Gg a^{-1}]	**2010**	**2011**	**2012**	**2013**						
N excretions, 2015	1287.8	1293.2	1311.5	1326.8						
N excretions, 2014	1264.0	1259.2	1267.5							

NO emissions, because they are directly proportional to N_2O emissions (cf. Chapter 5.3.4.2.2), have changed with respect to the corresponding figures in the 2014 NIR in the same manner that the N_2O emissions have changed. The changes in total NO emissions are shown in Table 236.

Table 236: Comparison of total NO emissions from manure management, as calculated for the 2015 NIR and as calculated for the 2014 NIR

[Gg a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
2015	1.772	1.572	1.544	1.543	1.450	1.450	1.458	1.426	1.396	1.392
2014	1.710	1.516	1.492	1.494	1.396	1.399	1.406	1.371	1.342	1.333
[Gg a^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
2015	1.382	1.409	1.378	1.371	1.344	1.358	1.342	1.355	1.362	1.369
2014	1.327	1.355	1.323	1.314	1.290	1.293	1.271	1.277	1.282	1.282
[Gg a^{-1}]	**2010**	**2011**	**2012**	**2013**						
2015	1.346	1.322	1.303	1.313						
2014	1.258	1.230	1.227							

5.3.4.6 Planned improvements (category-specific) (3.B, N_2O_{direct} & NO)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

5.3.5 Indirect N_2O emissions as a result of manure management (3.B)

5.3.5.1 Category description (3.B, $N_2O_{indirect}$)

Cf. Chapter 5.3.1.

5.3.5.2 Methodological issues (3.B, $N_2O_{indirect}$)

5.3.5.2.1 Methods (3.B, $N_2O_{indirect}$)

The indirect N_2O emissions resulting from deposition of NH_3 and NO from manure management (including manure digestion residues; not including application) are calculated, in keeping with IPCC (2006)-11.21, in proportion to the deposited N quantity:

Equation16: Indirect N_2O emissions as a result of manure management

$$E_{\mathrm{N2O indirect, MM}} = \frac{44}{28} \cdot (E_{\mathrm{NH3\text{-}N, MM}} + E_{\mathrm{NO\text{-}N, MM}}) \cdot EF_4$$

where:

$E_{\mathrm{N2O, indirect,-MM}}$	Indirect N_2O emissions from deposition of NH_3-N and NO-N from manure management (kg a^{-1})
$E_{\mathrm{NH3\text{-}N, MM}}$	Total NH_3-N emissions from manure management (not including application) (kg a^{-1})
$E_{\mathrm{NO\text{-}N, MM}}$	Total NO-N emissions from manure management (not including application) (kg a^{-1})
EF_4	N_2O-N emission factor; cf. Chapter 5.3.5.2.2

With regard to calculation of NH_3 and NO emissions from housing systems and from manure storage cf. RÖSEMANN et al. (2015).

Indirect N_2O emissions via leaching from manure management are not reported for Germany; cf. Chapter 5.3.1.

5.3.5.2.2 Emission factor (3.B, $N_2O_{indirect}$)

The emission factor for indirect N_2O emissions as a result of deposition of NH_3 and NO from manure management is *EF* = 0.01 kg kg^{-1} (IPCC (2006)-11.24, Table 11.3).

5.3.5.2.3 Emissions (3.B, $N_2O_{indirect}$)

Table 237 shows the indirect N_2O emissions resulting from deposition of reactive nitrogen via NH_3 and NO emissions from manure management. In general, the trend for indirect N_2O emissions follows the trend for direct N_2O emissions; cf. Chapter 5.3.4.2.3. With regard to the underlying quantities of reactive nitrogen, cf. Chapter 5.1.5.1.3.

Table 237: Indirect N_2O emissions resulting from deposition of NH_3 and NO from manure management (3.B(b))

[Gg a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	4.169	3.660	3.626	3.597	3.537	3.512	3.536	3.502	3.543	3.523
[Gg a^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
	3.489	3.540	3.484	3.535	3.464	3.501	3.454	3.494	3.492	3.506
[Gg a^{-1}]	**2010**	**2011**	**2012**	**2013**						
	3.418	3.423	3.472	3.502						

5.3.5.3 Uncertainties and time-series consistency (3.B, $N_2O_{indirect}$)

With regard to the uncertainties for the indirect N_2O emissions resulting from deposition of NH_3 and NO from manure management we call attention to Table 204 in Chapter 5.1.6 (total uncertainty of the German GHG inventory).

All emissions time series are consistent, since they were calculated with the same method for all years of the report period, and since the input data are also consistent and all data gaps have been filled in (cf. Chapter 5.1.7).

5.3.5.4 Category-specific quality assurance / control and verification (3.B, $N_2O_{indirect}$)

With regard to quality control and quality assurance, we refer to Chapter 5.1.7.

5.3.5.5 Category-specific recalculations (3.B, $N_2O_{indirect}$)

No recalculations can be carried out, since the emissions time series was calculated for the first time for the present 2015 NIR.

5.3.5.6 Planned improvements (category-specific) (3.B, $N_2O_{indirect}$)

No improvements are planned at present.

5.4 Rice cultivation (3.C)

No rice is cultivated in Germany (not occurring – NO).

5.5 Agricultural soils (3.D)

5.5.1 Category description (3.D)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T	3.D Agricultural Soils	0	N2O	28.292,9	(2,32%)	25.278,6	(2,70%)	-10,7%

Gas	Method used	Source for the activity data	Emission factors used
N_2O	Tier 1	M/AS/RS/NS	D
NO_X	Tier 1	RS/NS	D
NMVOC	Tier 1	RS/NS	D

With regard to *N_2O emissions*, the category *Agricultural soils* is a key category in terms of emissions level and trend.

Microbial transformations of N compounds (nitrification and denitrification) lead to emissions of N_2O from soils. A distinction is made between direct and indirect N_2O emissions. The direct emissions in Sector 3.D include the N_2O emissions resulting from:

- Application of mineral fertiliser
- Application of manure (including digestion residues of manure)
- Application of residues from digestion of energy crops
- Application of sewage sludge
- Grazing
- Crop residues
- Cultivation of organic soils

Mineralization / immobilization in connection with loss / addition of organic matter is not reported; it is assumed that no changes in the soil's C/N stocks occur. This assumption is based on the fact that results obtained from long-term soil monitoring on defined areas over the past 25 years showed no changes in 80 % of all cases, slight increases in 10 % of all cases and slight reductions in the remaining 10 % of all cases (A. Gensior, personal communication; cf. also 2014 NIR, Chapters 7.3.4.3 and 7.4.4.3).

The indirect N_2O emissions in Sector 3.D result from deposition of reactive nitrogen and from leaching and surface runoff.

In 2013, the total N_2O emissions of Sector 3.D were 10.7 % lower than they were in 1990. Their share of total N_2O emissions from the German agricultural sector was somewhat higher in 2013, at 85.9 %, than it was in 1990, when it was 84.7 %. In 1990, the greenhouse-gas emissions in Sector 3.D (in CO_{2eq}) accounted for a 36.3 % share of greenhouse-gas emissions from the agricultural sector as a whole. By 2013, that share had increased to 39.3 %. In addition, the greenhouse-gas emissions resulting solely from application of residues from digestion of energy crops were negligible in 1990, while in 2013 they accounted for 2.2 % of the entire agricultural sector's greenhouse-gas emissions.

The German inventory takes account of NMVOC emissions from agricultural crops. As a result of increasing harvests, those emissions increased by from 34.2 % from 1990 to 2013 – from 7.7 Gg (1990) to 10.3 Gg (2013).

5.5.2 Methodological aspects, and emissions (3.D)

5.5.2.1 Methods and emission factors (3.D)

5.5.2.1.1 Direct N_2O emissions (3.D.a)

Direct N_2O emissions resulting from application of N containing substrates, and from crop residues, are calculated, with a Tier 1 method pursuant to IPCC (2006)-11.7, in proportion to the pertinent applied N quantities (cf. Chapter 5.1.5.1). Pursuant to IPCC(2006)-11.11, Table 11.1, the relevant emission factor is 0.01 kg N_2O-N per kg of applied nitrogen.

Emissions from N excretions during grazing are calculated, pursuant to IPCC (2006)-11.7, in proportion to the N quantity excreted on pasture (cf. Chapter 5.1.5.1). The relevant emission factor for cattle is EF = 0.02 kg N_2O-N per kg of excreted nitrogen. For sheep, goats and horses, the N_2O-N emission factor is 0.01 kg kg^{-1}. (For swine and poultry, the inventory does not include any periods spent outdoors.)

Direct N_2O emissions from cultivation of organic soils are calculated in proportion to the relevant area, which is broken down into the categories of cropland and grassland (cf. Chapter 5.1.5.1.2). The pertinent emission factors have been derived from the German data that LEPPELT et al. (2014) have used for their Europe-wide study. For cropland, the emission factor thus obtained is 10.7 kg N_2O-N per ha, while for drained grassland it is 2.7 kg N_2O-N per ha. As a result of the year-to-year variance in the cropland and grassland areas, the average emission factor varies over time; cf. Table 238.

Table 238: Average N_2O and N_2O-N emission factors for cultivated organic soils

[kg kg^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
N_2O	8.3	8.3	8.2	8.2	8.2	8.1	8.1	8.1	8.0	8.0
N_2O-N	5.3	5.3	5.2	5.2	5.2	5.2	5.2	5.1	5.1	5.1
[kg kg^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
N_2O	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.8	7.8	7.8
N_2O-N	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	5.0
[kg kg^{-1}]	**2010**	**2011**	**2012**	**2013**						
N_2O	7.8	7.8	7.8	7.8						
N_2O-N	5.0	5.0	5.0	5.0						

5.5.2.1.2 Indirect N_2O emissions resulting from deposition of reactive nitrogen via use of agricultural soils (3.D)

Indirect N_2O emissions resulting from deposition of reactive nitrogen are calculated, pursuant to IPCC (2006)-11.21, in proportion to the pertinent N quantity deposited. The method is analogous to the approach described in Chapter 5.3.5.2.1. The total deposited N quantity of relevance for the calculations in Sector 3.D includes the N quantities of the following NH_3 and NO emissions (cf. Chapter 5.1.5.1.3):

- NH_3 and NO emissions from mineral-fertiliser application,
- NH_3 and NO emissions from application of manure (incl. manure digestion residues),
- NH_3 and NO emissions from application of residues from digestion of energy crops,
- NH_3 and NO emissions from grazing.

These emissions are obtained by multiplying the relevant applied N quantity or N excretions during grazing by the pertinent emission factor. The NH_3 emission factors for the various fertiliser categories are obtained from EMEP (2013)-3D. With regard to the NH_3 emission factors for application of manure and digestion residues, we refer to RÖSEMANN et al. (2015). The NH_3 emission factors for grazing are differentiated by type of animal; cf. EMEP (2013)-3B-27. With regard to the NO emission factor, cf. Chapter 5.5.2.1.4.

A detailed description of calculation of indirect N_2O emissions from agricultural soils is provided by RÖSEMANN et al. (2015).

5.5.2.1.3 Indirect N_2O emissions resulting from leaching and surface runoff (3.D)

In keeping with the Tier 1 method pursuant to IPCC (2006)-11.21, indirect N_2O emissions resulting from leaching and surface runoff are calculated as the product of the N_2O-N conversion factor 44/28, the N quantity leached (cf. Chapter 5.1.5.1.4) and the emission factor (0.0075 kg N2O-N (kg N)$^{-1}$; IPCC (2006)-11.24, Table 11.3).

A detailed description of calculation of indirect N_2O emissions from agricultural soils is provided by RÖSEMANN et al. (2015).

5.5.2.1.4 NO emissions

The procedure for calculating NO emissions is described in Chapter 5.5.2.1.2. The following table shows the emission factors used. Neither EMEP (2013) nor EMEP (2009) provides a procedure for calculating NO emissions resulting from grazing. For this reason, we use the emission factor given in EMEP(2007)-B1020-12, Chapter 4.3.

Table 239: Emission factors EF_{NO} for NO emissions from agricultural soils

	EF_{NO} kg kg^{-1} NO-N]	**Remark**
Application of mineral fertiliser, manure and digestion residues	0.012	EMEP (2013)-3D-11, pursuant to STEHFEST & BOUWMAN (2006)
Grazing	0.007	EMEP (2007), B1020-12

5.5.2.1.5 NMVOC emissions

IPCC provides no method for calculation of the NMVOC emissions from agricultural crops that are to be reported under CRF 3s2. In keeping with EMEP (2013)-3D-32 ff, Germany calculates the pertinent NMVOC emissions separately by crops:

Equation 17: The EMEP method for calculation of annual NMVOC emissions from agricultural crops

$$E_{\mathrm{NMVOC,\,cult,i}} = \beta \cdot A_{\mathrm{i}} \cdot m_{\mathrm{FM,i}} \cdot x_{\mathrm{DM,i}} \cdot t_{\mathrm{i}} \cdot EF_{\mathrm{NMVOC,\,cult,i}}$$

Where

$E_{NMVOC, cult, i}$	NMVOC emissions from agricultural crop i (in kg a^{-1})
β	Conversion factor for time units (8760 h a^{-1})
A_i	Area under cultivation with crop i (in ha)
$m_{FM, i}$	Average fresh-mass yield from crop i (in kg ha^{-1})
$m_{FM, i}$	Dry-matter content of crop i (in kg ha^{-1})
t_i	Fraction of the year during which crop i emits NMVOCs (in a a^{-1})
$EF_{NMVOC, cult, i}$	NMVOC emission factor for crop i (in kg kg^{-1} h^{-1})

With regard to areas under cultivation, fresh-mass yields, dry-matter content and relative duration of emissions, cf. Chapter 5.1.5.2. The emission factors for wheat, rye, rape and grass were obtained from EMEP (2013)-3D-34, Table A3-2; cf. Table 240. For the crop categories "grass clover ley, alfalfa, forage grass" and "pastures and meadows", the EMEP emission factor for grass has been used. For the remaining crops, the EMEP emission factor for wheat has been used.

Table 240: NMVOC emission factors for agricultural crops

Crop	Emission factor [kg kg^{-1} h^{-1}]
Wheat	$2.60 \cdot 10^{-8}$
Rye	$1.41 \cdot 10^{-7}$
Rape	$2.02 \cdot 10^{-7}$
Grass (15 °C)	$1.03 \cdot 10^{-8}$

5.5.2.2 *Frac* values (3.D)

Germany reports on $Frac_{GASF}$, $Frac_{GASM}$ and $Frac_{leach.}$

In the German inventory, $Frac_{LEACH}$ is an input value. It shows the relative fraction of N inputs into the soil that is lost via leaching and surface runoff. The German inventory uses the IPCC default value $Frac_{LEACH}$ = 0.30 kg kg^{-1} (IPCC (2006)-11.24, Table 11.3); cf. Chapter 5.1.5.1.4.

The values $Frac_{GASF}$ and $Frac_{GASM}$, on the other hand, are not used in the inventory. Once the emission calculations are terminated $Frac_{GASF}$ and $Frac_{GASM}$ are determined, for purposes of reporting, from input and output data .

Pursuant to IPCC (2006)-11.21, Equation 11.9, $Frac_{GASF}$ denotes the fraction of the N quantity applied via mineral fertiliser that is emitted as NH_3-N and NO-N; cf. Table 241.

Table 241: $Frac_{GASF}$ (3.D)

[kg kg^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
$Frac_{GASF}$	0.061	0.060	0.059	0.062	0.063	0.064	0.065	0.066	0.067	0.068
[kg kg^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
$Frac_{GASF}$	0.068	0.075	0.076	0.076	0.077	0.073	0.077	0.081	0.077	0.094
[kg kg^{-1}]	**2010**	**2011**	**2012**	**2013**						
$Frac_{GASF}$	0.078	0.084	0.080	0.085						

Pursuant to IPCC (2006)-11.21, Equation 11.9, $Frac_{GASM}$ denotes the fraction of the N quantity applied via manure(incl. manure digestion residues), residues from digestion of energy crops, sewage sludge and grazing that is emitted as NH_3-N and NO-N; cf. Table 242. (The $Frac_{GASM}$ definition in CRF 3.D is not the same as this definition and is thus ignored in German reporting.)

Table 242: *Frac*GASM (3.D)

[kg kg-1]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
*Frac*GASM	0.195	0.197	0.195	0.194	0.185	0.183	0.182	0.181	0.181	0.180
[kg kg-1]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
*Frac*GASM	0.178	0.178	0.177	0.176	0.175	0.174	0.174	0.173	0.173	0.172
[kg kg-1]	**2010**	**2011**	**2012**	**2013**						
*Frac*GASM	0.173	0.175	0.171	0.171						

5.5.2.3 Emissions (3.D)

Table 243 presents an overview of the contributions of the various individual sub-sources to overall N_2O emissions from agricultural soils. The indirect emissions also include the contributions resulting from application of residues from digestion of energy crops.

Table 243: Overview of N_2O emissions from agricultural soils (3.D)

[Gg a-1]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total emissions	94.94	88.61	85.44	83.74	78.59	82.96	82.93	82.99	83.65	86.16
Total, direct emissions	76.94	72.01	69.50	68.12	64.03	67.54	67.50	67.58	68.09	70.09
Total, indirect emissions	18.01	16.60	15.94	15.62	14.56	15.43	15.43	15.42	15.56	16.07
Mineral fertiliser	34.00	31.61	30.28	28.44	25.33	28.09	27.80	27.61	28.09	29.89
Manure	18.10	16.14	15.84	15.76	15.83	15.75	15.84	15.56	15.58	15.53
Residues from digestion of energy crops	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.04	0.05
Sewage sludge	0.43	0.43	0.41	0.41	0.41	0.55	0.55	0.54	0.50	0.50
Grazing	6.41	5.80	5.73	5.78	4.99	5.08	5.13	5.02	4.97	4.97
Crop residues	7.61	7.67	6.90	7.43	7.20	7.82	7.96	8.65	8.78	9.04
Organic soils	10.39	10.36	10.33	10.30	10.27	10.24	10.21	10.18	10.15	10.11
Indirect; deposition; not including energy crops [a]	6.34	5.74	5.54	5.49	5.10	5.28	5.29	5.24	5.26	5.38
Indirect; deposition; energy crops [a]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Indirect; leaching; not including energy crops [a]	11.67	10.86	10.40	10.12	9.46	10.14	10.13	10.18	10.28	10.67
Indirect; leaching; energy crops [a]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
[Gg a-1]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Total emissions	87.60	85.46	82.52	81.15	84.12	82.59	81.97	79.08	84.73	81.25
Total, direct emissions	71.24	69.42	67.04	65.90	68.35	67.12	66.53	64.16	68.73	65.72
Total, indirect emissions	16.36	16.04	15.48	15.24	15.77	15.47	15.44	14.92	16.00	15.52
Mineral fertiliser	31.64	29.02	28.16	28.09	28.72	27.95	28.03	25.14	28.40	24.37
Manure	15.29	15.52	15.14	15.07	14.74	14.83	14.59	14.75	14.82	14.97
Residues from digestion of energy crops	0.08	0.11	0.16	0.19	0.25	0.68	0.96	1.30	1.52	1.93
Sewage sludge	0.52	0.47	0.44	0.46	0.44	0.43	0.42	0.43	0.42	0.43
Grazing	4.84	4.85	4.58	4.47	4.34	4.24	4.12	4.08	4.11	4.10
Crop residues	8.79	9.42	8.60	7.72	10.02	9.22	8.62	8.66	9.66	10.12
Organic soils	10.08	10.02	9.96	9.90	9.84	9.78	9.79	9.79	9.80	9.80
Indirect; deposition; not including energy crops [a]	5.41	5.46	5.31	5.27	5.25	5.08	5.12	5.02	5.15	5.27
Indirect; deposition; energy crops [a]	0.02	0.02	0.03	0.04	0.05	0.13	0.19	0.26	0.30	0.38
Indirect; leaching; not including energy crops [a]	10.92	10.54	10.11	9.90	10.43	10.15	9.97	9.43	10.30	9.56
Indirect; leaching; energy crops [a]	0.01	0.02	0.03	0.03	0.04	0.11	0.16	0.21	0.25	0.31

[Gg a^{-1}]	2010	2011	2012	2013
Total emissions	80.41	85.51	84.08	84.83
Total, direct emissions	65.21	69.05	68.05	68.53
Total, indirect emissions	15.20	16.45	16.03	16.30
Mineral fertiliser	24.66	28.07	25.78	25.91
Manure	14.85	14.97	15.22	15.41
Residues from digestion of energy crops	2.43	3.03	3.39	3.52
Sewage sludge	0.44	0.42	0.42	0.42
Grazing	4.05	3.97	3.95	4.00
Crop residues	8.98	8.79	9.49	9.49
Organic soils	9.80	9.80	9.81	9.78
Indirect; deposition; not including energy crops [a]	4.89	5.34	5.03	5.21
Indirect; deposition;energy crops [a]	0.48	0.60	0.64	0.66
Indirect; leaching; not including energy crops [a]	9.44	10.02	9.81	9.84
Indirect; leaching; energy crops [a]	0.39	0.49	0.56	0.58

[a] Energy crops: Residues from digestion of energy crops

As Table 243 clearly shows, an emissions decrease took place from 1990 to 1992. In the years as of 1993, no clear trend emerges; the N_2O emissions fluctuate around a mean value of 83.2 Gg a^{-1} N_2O. The pertinent emissions maximum in the entire time series, 94.9 Gg a^{-1} N_2O, occurred in 1990, while the minimum, 78.6 Gg a^{-1} N_2O, occurred in 1994. The fractional contributions to the total emissions in 2013 included the following: application of mineral fertiliser, 30:5 %; application of manure (incl. manure digestion residues) and residues from digestion of energy crops, 22.3 %; cultivation of organic soils, 11.5 %; crop residues, 11.2 %; grazing, 4.7 %; and sewage sludge, 0.5 %. The remaining 19.2 % are indirect emissions.

The trend in total emissions is shaped largely by fluctuations in N_2O emissions from mineral-fertiliser application. Those fluctuations, in turn, result from year-to-year variations in the N quantity related to mineral fertiliser (cf. Chapter Table 196 in Chapter 5.1.5.1.1).

The results of the NO-emissions calculations are shown in Table 244. In keeping with the remarks made in Chapter 5.5.2.1.2, those calculations cover the NO emissions resulting from application of mineral fertiliser and manure (including manure digestion residues) and from grazing (both emissions categories are summarised under "animal husbandry, mineral fertiliser"), while the NO emissions resulting from application of residues from digestion of energy crops are listed separately. The trend for the total emissions largely follows that for the N_2O emissions. (For purposes of reporting in CRF 3s2, the NO values are converted into NO_2, via multiplication by the molar ratio 46/30.)

Table 244: NO emissions from agricultural soils

[Gg a-1]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total	**88.5**	**81.0**	**78.4**	**75.2**	**69.9**	**74.3**	**74.0**	**73.2**	**74.0**	**76.9**
Animal husbandry, mineral fertiliser	88.4	81.0	78.4	75.2	69.9	74.3	74.0	73.2	74.0	76.8
Residues from digestion of energy crops	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
[Gg a-1]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Total	**79.4**	**75.5**	**73.4**	**73.2**	**73.7**	**73.3**	**73.4**	**69.5**	**75.3**	**69.6**
Animal husbandry, mineral fertiliser	79.2	75.3	73.2	72.9	73.3	72.1	71.8	67.4	72.8	66.5
Residues from digestion of energy crops	0.1	0.2	0.3	0.3	0.4	1.1	1.6	2.1	2.5	3.2
[Gg a-1]	**2010**	**2011**	**2012**	**2013**						
Total	**70.7**	**77.4**	**74.6**	**75.4**						
Animal husbandry, mineral fertiliser	66.7	72.4	69.1	69.6						
Residues from digestion of energy crops	4.0	5.0	5.5	5.8						

Table 245 shows the trend for NMVOC emissions, which increased by somewhat more than one-third (34.2 %) in the period 1990 through 2013. Those increases resulted from yield increases in the period 1990 through 2013; cf. Chapter 5.1.5.2.

Table 245: NMVOC emissions from agricultural crops

[Gg a-1]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	7.69	7.83	7.00	7.70	7.50	8.19	7.85	8.58	8.85	9.06
[Gg a-1]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
	8.79	9.48	8.60	7.28	9.81	9.17	8.83	9.19	9.83	10.63
[Gg a-1]	**2010**	**2011**	**2012**	**2013**						
	9.49	8.99	10.02	10.32						

5.5.3 Category-specific quality assurance / control and verification (3.D)

With regard to quality control and quality assurance, we refer to Chapter 5.1.7.

For purposes of verification, Table 246 presents the Frac values $Frac_{GASF}$ and $Frac_{GASM}$, as determined for Germany, in a comparison with the corresponding data of countries that either are neighbouring countries or have agricultural practices comparable to those prevailing in Germany.

The scattering seen in the $Frac_{GASF}$ data can be attributed to the variation, among the neighbouring countries, seen in the relative shares of different fertiliser types (with their different NH_3 emission factors). The values thus hardly lend themselves to comparison. The German value, 0.08 kg kg^{-1}, is smaller than the IPCC (2006) default value of 0.10 kg kg^{-1}. With the exception of the Netherlands, whose value of 0.07 kg kg^{-1} is nearly the same as the German value, those countries that do not use the IPCC default value show considerably lower $Frac_{GASF}$ values (0.03 to 0.04 kg kg^{-1}).

A considerable range is also seen in the $Frac_{GASM}$ values. It ranges from the values calculated by Germany and the Netherlands, 0.17 kg kg^{-1}, to the much higher Swiss value of 0.40 kg kg^{-1}. The mean value for the other countries (i.e. not including Switzerland) is 0.20 kg kg^{-1}. That value, the IPCC (2006) default value, is used directly by the Czech Republic, France, Poland and the UK.

With regard to $Frac_{LEACH}$, it is worthy of note that most neighbouring countries use the IPCC default value. Use of other $Frac_{LEACH}$ values cannot be understood without additional information.

Table 246: Comparison of the *Frac* values used in the German inventory with those of neighbouring countries, for the year 2012

[kg kg^{-1}]	*Frac*$_{GASF}$	*Frac*$_{GASM}$	*Frac*$_{LEACH}$
Austria	0.04	0.27	0.30
Belgium	0.04	0.21	0.13
Czech Republic	0.10	0.20	0.30
Denmark	0.03	0.19	0.33
France	0.10	0.20	0.30
Germany	**0.08**	**0.17**	**0.30**
Netherlands	0.07	0.17	0.12
Poland	0.10	0.20	0.30
Switzerland	0.04	0.40	0.20
UK	0.10	0.20	0.30
IPCC(2006)-11.13, 11.14, 11.24	0.100	0.200	

Source: Germany: Submission 2015; other countries: UNFCCC 2014

5.5.4 Uncertainties and time-series consistency (3.D)

With regard to the uncertainties in the area of N_2O emissions from agricultural soils, the reader's attention is called to Table 204 in Chapter 5.1.6 (total uncertainty of the German GHG inventory).

For NO, EMEP (2013)-3D-18, with reference to Stehfest and Bouwman (2006), gives a 95 % confidence interval of -80 % to +406 % (with respect to the emission factor). In contrast to the interpretation provided in EMEP (2013)-3D-18, that result is equivalent to an uncertainty factor of about 5.

The NMVOC emissions result is subject to large uncertainties (EMEP (2013)-3D-5, EMEP (2013)-3D-7, EMEP (2013)-3D-34). The Tier 1 emission factors in EMEP (2013)-3D-11, Table 3-1, list an uncertainty factor of 4.

All emissions time series are consistent, since they were calculated with the same method for all years of the report period, and since the input data are also consistent and all data gaps have been filled in (cf. Chapter 5.1.7).

5.5.5 Category-specific recalculations (3.D)

The changes in N_2O emissions from agricultural soils that have resulted with regard to the 2014 NIR are presented in the following Table 247:

Table 247: Total N_2O from agricultural soils, as listed in the 2014 NIR and the 2015 NIR (3.D)

[Gg a^{-1}]	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
2015	94.9	88.6	85.4	83.7	78.6	83.0	82.9	83.0	83.7	86.2
2014	153.8	142.3	136.5	135.4	126.8	133.7	134.4	134.7	135.8	139.0
[Gg a^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
2015	87.6	85.5	82.5	81.1	84.1	82.6	82.0	79.1	84.7	81.2
2014	141.0	137.5	133.0	129.5	135.9	133.4	130.9	127.3	135.4	129.1
[Gg a^{-1}]	**2010**	**2011**	**2012**	**2013**						
2015	80.4	85.5	84.1	84.8						
2014	126.6	134.7	132.0							

The sharp reduction with respect to the 2014 NIR is due primarily to the emissions decrease in the four sub-sources mineral-fertiliser application, crop residues, organic soils and leaching / surface runoff (in 1990, to a degree of 91.5 %; in 2012, to a degree of 99.9 %), with the largest change occurring in the emissions from leaching / surface runoff. Table 248 compares the 2014-NIR and 2015-NIR time series for these four sub-sources.

Table 248: Comparison of N_2O emissions from mineral-fertiliser application, crop residues, cultivation of organic soils and leaching / surface runoff, as reported in the 2014 NIR and as reported in the 2015 NIR (3.D)

[Gg a-1]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Mineral fertilisers, 2015	34.0	31.6	30.3	28.4	25.3	28.1	27.8	27.6	28.1	29.9
Mineral fertilisers, 2014	41.0	38.2	36.6	34.3	30.5	33.8	33.4	33.2	33.7	35.9
Crop residues, 2015	7.6	7.7	6.9	7.4	7.2	7.8	8.0	8.7	8.8	9.0
Crop residues, 2014	16.5	15.7	14.3	15.7	14.5	15.4	16.0	16.8	16.8	17.0
Organic soils, 2015	10.4	10.4	10.3	10.3	10.3	10.2	10.2	10.2	10.1	10.1
Organic soils, 2014	15.8	15.8	15.8	15.7	15.7	15.7	15.7	15.7	15.7	15.7
Indirect, leaching, 2015	11.7	10.9	10.4	10.1	9.5	10.1	10.1	10.2	10.3	10.7
Indirect, leaching, 2014	43.7	40.1	38.2	37.8	35.1	37.5	37.7	37.8	38.2	39.3
[Gg a-1]	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Mineral fertilisers, 2015	31.6	29.0	28.2	28.1	28.7	27.9	28.0	25.1	28.4	24.4
Mineral fertilisers, 2014	38.0	34.7	33.7	33.6	34.3	33.5	33.5	30.0	34.0	28.8
Crop residues, 2015	8.8	9.4	8.6	7.7	10.0	9.2	8.6	8.7	9.7	10.1
Crop residues, 2014	16.7	17.3	16.3	14.3	18.3	17.5	16.3	17.5	18.8	19.6
Organic soils, 2015	10.1	10.0	10.0	9.9	9.8	9.8	9.8	9.8	9.8	9.8
Organic soils, 2014	15.7	15.7	15.6	15.6	15.6	15.6	15.5	15.5	15.5	15.4
Indirect, leaching, 2015	10.9	10.6	10.1	9.9	10.5	10.3	10.1	9.6	10.5	9.9
Indirect, leaching, 2014	40.1	38.8	37.4	36.2	38.5	37.7	36.8	35.6	38.4	36.2
[Gg a-1]	2010	2011	2012	2013						
Mineral fertilisers, 2015	24.7	28.1	25.8	25.9						
Mineral fertilisers, 2014	29.5	33.4	30.8							
Crop residues, 2015	9.0	8.8	9.5	9.5						
Crop residues, 2014	17.8	19.0	19.9							
Organic soils, 2015	9.8	9.8	9.8	9.8						
Organic soils, 2014	15.4	15.4	15.3							
Indirect, leaching, 2015	9.8	10.5	10.4	10.4						
Indirect, leaching, 2014	35.5	38.3	37.4							

The reduction in the mineral fertiliser category results primarily from use of the new emission factor (0.01 kg kg^{-1}, pursuant to IPCC (2006), instead of the former 0.0125 kg kg^{-1}, pursuant to IPCC (1996b)).

This new emission factor also has an impact in the crop residues category. Furthermore, the error correction mentioned in Chapter 5.1.5.1.1 results in a considerable decrease in the N quantity available in the soil as a result of crop residues.

The reasons for the reduction in the organic soils category is that the current national emission factor is about 5 kg N_2O-N per ha (cf. Chapter 5.5.2.1.1), while the 2014 NIR used the IPCC (2000) default emission factor of 8 kg N_2O-N per ha.

The reduction in the indirect N_2O emissions from leaching / surface runoff is due mainly to the use of the IPCC (2006) emission factor (cf. Chapter 5.5.2.1.3), which is only 30 % as large as the IPCC (1996b) emission factor used in the 2014 NIR. A nearly unnoticeable partial compensation results via the emissions allocated to application of residues from digestion of energy crops, emissions which were not yet being reported in the 2014 NIR.

Table 249 compares the total NO emissions with the corresponding data from the 2014 NIR. The changes are due very largely to the inclusion of NO emissions from application of residues from digestion of energy crops.

Table 249: Total NO from agricultural soils, as listed in the 2014 NIR and the 2015 NIR (3.D)

[Gg a-1]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
2015	88.5	81.0	78.4	75.2	69.9	74.3	74.0	73.2	74.0	76.9
2014	88.5	81	78.4	75.3	69.9	74.4	74.1	73.1	73.9	76.7
[Gg a-1]	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
2015	79.4	75.5	73.4	73.2	73.7	73.3	73.4	69.5	75.3	69.6
2014	79.2	75.3	73.1	72.7	73.2	72	71.6	67.1	72.6	66.1
[Gg a-1]	2010	2011	2012	2013						
2015	70.7	77.4	74.6	75.4						
2014	66.4	71.9	68.4							

In the NMVOC-emissions category, no comparison with last year's report (2014 NIR) is possible, since it did not include any NMVOC-emissions calculation.

5.5.6 Planned improvements (category-specific) (3.D)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

5.6 Prescribed burning of savannas (clearance of land by prescribed burning) (3.E)

Land clearance by prescribed burning is not practiced in Germany (NO).

5.7 Field burning of agricultural residues (3.F)

Burning of agricultural residues is prohibited in Germany. It is not possible to collect data on permitted exceptions. Such exceptions are considered to be irrelevant (NO).

5.8 CO_2 emissions from liming and urea application (3.G-I)

5.8.1 Category description

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/T	**3.G Liming**		**CO2**	**1.276,9**	**(0,10%)**	**1.956,5**	**(0,21%)**	**53,2%**
-/-	3.H Urea application		CO2	479,6	(0,04%)	695,0	(0,07%)	44,9%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1	NS	D

The category Liming is a key category for CO2 by the emission trend.

Liming, i.e. addition of carbonates to the soil, reduces the soil's acidity. It enhances plant growth, releasing CO_2 in the process. Lime fertilisers include all carbonates of calcium and magnesium, either as pure substances or as additives. Under CRF 3.G, Germany reports all CO_2 emissions that result from application of calcium-carbonate, compound-lime, carbolic-lime and residual-lime fertilisers and of calcium ammonium nitrate. For this reason, "IE" is listed under CRF 3.I ("other lime fertilisers"). In keeping with the requirement in the CRF tables, the reported CO_2 emissions include both the pertinent emissions from the agricultural sector and those from liming in the forestry sector.

Nitrogen fertilisation with urea leads to CO_2 emissions via reactions involving urease and water. Germany reports such CO_2 emissions in Sector 3.H, without consideration of CO_2 bound via industrial production of urea fertiliser.

From 1990 through 2013, the calculated CO_2 emissions from liming increased from 1276.9 Gg a^{-1} to 1956.5 Gg a^{-1}, or by 53.2 %. During the same period, the calculated CO_2 emissions from urea application increased by 44.9 %, from 479.6 Gg a^{-1} to 695.0 Gg a^{-1}.

5.8.2 Methods and emissions

The CO_2-C emissions from liming are calculated, via a Tier 1 method (IPCC (2006)-11.27), as the product of the quantity of lime applied (in $CaCO_3$; cf. Chapter 5.1.5.2) and the CO_2-C emission factor, which is related to $CaCO_3$. The emission factor, which is to be derived stoichiometrically, is given by IPCC (2006)-11.27 as 0.12 kg CO_2-C per kg of $CaCO_3$. In the CRF tables, the pertinent emissions are to be given in units of CO_2; this is made possible via multiplication by the molar ratio 44/12 (IPCC (2006)-11.27).

Table 250 shows the trend for CO_2 emissions from liming, as total quantities and broken down into the contributions from agriculture and from forestry. The activity data for CRF Sector 3.I are listed in Table 201.

Table 250: CO_2 emissions from liming (3.G)

[Gg a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total	**1276.9**	**1285.9**	**1234.0**	**1216.1**	**1410.6**	**1643.9**	**1642.3**	**1722.6**	**1901.9**	**1955.8**
Agriculture	1160.0	1170.9	1071.5	1091.3	1256.7	1498.3	1498.3	1575.4	1752.2	1818.4
Forestry	116.9	115.0	162.5	124.8	153.9	145.5	144.0	147.2	149.6	137.4
[Gg a-1]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Total	**2144.2**	**1833.1**	**1902.9**	**1756.1**	**1763.0**	**1680.8**	**1614.6**	**1740.2**	**1798.6**	**1750.1**
Agriculture	2024.0	1715.3	1772.9	1647.0	1681.1	1611.3	1548.6	1672.8	1746.2	1684.6
Forestry	120.2	117.8	130.1	109.1	82.0	69.6	66.0	67.4	52.4	65.5
[Gg a-1]	**2010**	**2011**	**2012**	**2013**						
Total	**1698.0**	**1842.0**	**1907.2**	**1956.5**						
Agriculture	1639.7	1777.6	1846.1	1888.4						
Forestry	58.3	64.4	61.1	68.1						

The Tier 1 method for CO_2-C emissions from urea application (IPCC (2006)-11.32) calculates the emissions in proportion to the quantity of urea applied (cf. Chapter 5.1.5.2). The proportionality factor used in the procedure is the CO_2-C emission factor, which is to be stoichiometrically derived. IPCC (2006)-11.32 gives it as 0.2 kg CO_2-C per kg of urea. Conversion into units of CO_2, as required for the CRF tables, is analogous to the conversion for CO_2 from liming; see above. Table 251 presents the resulting time series.

Table 251: CO_2 emissions from urea application (3.H)

[Gg a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	479.6	**433.7**	**397.9**	**451.0**	**417.5**	**477.2**	**480.9**	**496.1**	**516.2**	**559.8**
[Gg a-1]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
	578.5	**641.1**	**645.4**	**633.4**	**671.5**	**598.0**	**653.8**	**641.0**	**647.9**	**795.0**
[Gg a-1]	**2010**	**2011**	**2012**	**2013**						
	587.4	**749.9**	**624.8**	**695.0**						

5.8.3 Category-specific quality assurance / control and verification

With regard to quality control and quality assurance, we refer to Chapter 5.1.7.

5.8.4 Uncertainties and time-series consistency

With regard to the uncertainties in the area of CO_2 emissions from liming and urea application, the reader's attention is called to Table 204 in Chapter 5.1.6 (total uncertainty of the German GHG inventory). For details, cf. RÖSEMANN et al. (2015).

Normally, not all of the carbon applied is converted into CO_2, but this fact cannot be taken into account, since it is not possible to quantify the C quantity that is actually converted into CO_2. The calculated emissions thus represent the maximum possible emissions in the framework of the uncertainties listed in Table 204 in Chapter 5.1.6.

5.8.5 Category-specific recalculations

The emissions time series have been calculated with the same methods for the entire period as of 1990. No comparison with corresponding figures in last year's report (2014 NIR) is possible, since these emissions were not included in that report.

5.8.6 Planned improvements

No improvements are planned at present.

5.9 CH_4 and N_2O from digestion of energy crops (digesters and systems for storage of digestion residues) (3.J)

5.9.1 Category description

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/T	**3.J Other**		**CH4**	**0,3**	**(0,00%)**	**1.115,4**	**(0,12%)**	**398015,3%**
-/-	3.J Other		N2O	0,1	(0,00%)	228,8	(0,02%)	195950,1%

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	Q/RS/NS	CS/D
N_2O_{direct}	Tier 2	Q/RS/NS	CS/D
$N_2O_{indirect}$	Tier 1	Q/RS/NS	D
NO_X	Tier 2	Q/RS/NS	CS

The category 3.J Other is a key category for CH_4 , in terms of the emissions trend.

Digestion of energy crops is carried out primarily for purposes of energy generation. For this reason, the emissions occurring during digestion itself (digester) and in storage of digestion residues (CH_4, N_2O and NO; cf. Chapter 5.1.4.1) are reported on as a separate category (CRF 3s2/J). (The emissions resulting via use of digestion residues as fertiliser are reported in conjunction with reporting on emissions from application of other fertilisers, under 3.D.).

In a procedure analogous to that used for manure, the indirect N_2O emissions connected to storage of residues from digestion of energy crops are calculated as a result of deposition of reactive nitrogen. In addition, it is assumed, as in the case of manure, that no indirect N_2O emissions result from leaching / surface runoff from storage systems.

In the period 1990 through 2013, the calculated total emissions increased in keeping with the sharp growth that occurred in digestion of energy crops (cf. Chapter 5.1.4.2), from 0.4 Gg CO_{2eq} annually to 1344.1 Gg a^{-1} CO_{2eq} (2.1 % of the GHG emissions of the entire agricultural sector). Also from 1990 through 2013, the fraction of N_2O within those total emissions decreased from about 29 % to 17 %, as a result of increasing use of gas-tight storage.

5.9.2 Methodological issues

The procedure for calculating CH_4 emissions and direct N_2O emissions is analogous to that for calculation of emissions from manure digestion (cf. Chapter 5.1.3.6.5), with the exception that it does not take pre-storage into account.

As for manure (cf. Chapter 5.3.5), indirect N_2O emissions from storage of residues from digestion of energy crops are calculated as a result of deposition of reactive nitrogen. In the case of energy crops, such nitrogen originates in NH_3 and NO emissions from systems for storage of residues from digestion of energy crops. Also as for the manure category, NO emissions from systems for storage of digestion residues are calculated via a procedure similar to that for calculation of N_2O emissions (cf. Chapter 5.3.4.2). With regard to calculation of NH_3 emissions from systems for storage of residues from digestion of energy crops, we refer to RÖSEMANN et al. (2015).

5.9.3 CH_4 emission factor and emissions (3.J, CH_4)

Table 252 shows the chronological sequence for the CH_4 emission factor for digestion of energy crops (digesters and systems for storage of digestion residues), related to the VS quantities that are input into the digestion process along with energy crops (cf. Chapter 5.1.4.2). The decrease in the emission factor over time results from increasing use of gas-tight storage for digestion residues (cf. Chapter 5.1.4.2). For such storage, only the CH_4 leakage rate has to be taken into account, instead of the higher emission factor for open storage.

Table 252: CH_4 emission factor for digestion of energy crops (digesters and systems for storage of digestion residues), related to the VS quantities input into digestion along with energy crops

[Gg Gg^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	0.00333	0.00332	0.00332	0.00331	0.00330	0.00329	0.00328	0.00327	0.00326	0.00325
[Gg Gg^{-1}]	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	0.00324	0.00323	0.00322	0.00321	0.00319	0.00318	0.00313	0.00308	0.00302	0.00297
[Gg Gg^{-1}]	2010	2011	2012	2013						
	0.00292	0.00287	0.00275	0.00275						

The CH_4 emissions from digestion of energy crops (digesters and systems for storage of digestion residues) are shown in Table 253. The noticeably increasing trend is a result of sharp increases in the quantities of energy crops being digested (cf. Chapter 5.1.4.2) – which have occurred especially since 2005. This trend is only slightly offset via increasing use of gas-tight systems for storage of digestion residues.

Table 253: CH_4 emissions from digestion of energy crops (digesters and systems for storage of digestion residues)

[Gg a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	0.01	0.03	0.04	0.05	0.06	0.14	0.24	0.30	0.67	0.77
[Gg a^{-1}]	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	1.21	1.72	2.48	2.93	3.79	10.16	14.03	18.68	21.43	26.70
[Gg a^{-1}]	2010	2011	2012	2013						
	32.89	40.21	42.90	44.62						

5.9.4 N_2O emission factors and emissions (3.J, N_2O)

The emission factors for direct N_2O emissions from digestion of energy crops (systems for storage of digestion residues) are shown in Table 254. These data represent the average values for gas-tight and open storage. In their decreasing trend, they represent the increasing use that has occurred, over the years, of gas-tight storage, which emits no N_2O. The emission factors in Table 254 are to be applied to the N quantities that are input, along with energy crops, into the digestion process (cf. Chapter 5.1.4.2).

Table 254: Implied N_2O-N emission factor for direct N_2O emissions from digestion of energy crops (systems for storage of digestion residues), related to the N quantities input via energy crops

[Gg Gg^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	0.00500	0.00495	0.00491	0.00486	0.00481	0.00477	0.00472	0.00467	0.00462	0.00458
[Gg Gg^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
	0.00453	0.00448	0.00444	0.00436	0.00429	0.00421	0.00395	0.00368	0.00341	0.00315
[Gg Gg^{-1}]	**2010**	**2011**	**2012**	**2013**						
	0.00289	0.00263	0.00203	0.00203						

The emission factor for indirect N_2O emissions as a result of deposition of NH_3 and NO from storage of residues from digestion of energy crops, like that for the comparable process in connection with manure, is $EF = 0.01$ kg kg^{-1} (IPCC (2006)-11.24, Table 11.3). To obtain the relevant emissions, this emission factor has to be multiplied by the N quantities that are deposited – which are given in Chapter 5.1.5.1.3.

The calculated direct and indirect N_2O emissions are presented in Table 255. The trend reflects the sharp increase that has occurred in digested quantities of energy crops (cf. Chapter 5.1.4) – especially since 2005.

Table 255: N_2O emissions from storage of residues from digestion of energy crops

[Gg a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total	**0.000**	**0.001**	**0.001**	**0.002**	**0.002**	**0.005**	**0.008**	**0.010**	**0.022**	**0.025**
N_2O_{direct}	0.000	0.001	0.001	0.002	0.002	0.005	0.008	0.009	0.021	0.024
$N_2O_{indirect}$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
[Gg a^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Total	**0.040**	**0.056**	**0.079**	**0.093**	**0.118**	**0.314**	**0.413**	**0.521**	**0.564**	**0.659**
N_2O_{direct}	0.038	0.053	0.076	0.088	0.113	0.298	0.393	0.496	0.536	0.627
$N_2O_{indirect}$	0.002	0.003	0.004	0.005	0.006	0.015	0.020	0.025	0.028	0.032
[Gg a^{-1}]	**2010**	**2011**	**2012**	**2013**						
Total	**0.758**	**0.858**	**0.736**	**0.768**						
N_2O_{direct}	0.721	0.816	0.700	0.730						
$N_2O_{indirect}$	0.037	0.042	0.036	0.038						

5.9.5 NO emission factors and emissions (3.J, NO)

As for the case of manure (cf. Chapter 5.3.4.2.2), the relevant NO emissions are calculated in proportion to the direct N_2O emissions, via use of the NO-N emission factor, which is to be applied to the input N quantity; that factor is set to 10 % of the N_2O-N emission factor.

Table 256 shows the trend in NO emissions from digestion of energy crops (systems for storage of digestion residues).

Table 256: NO emissions from storage of residues from digestion of energy crops

[Gg a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.003	0.003
[Gg a^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
	0.005	0.007	0.010	0.012	0.015	0.041	0.054	0.068	0.073	0.086
[Gg a^{-1}]	**2010**	**2011**	**2012**	**2013**						
	0.098	0.111	0.096	0.100						

5.9.6 Category-specific quality assurance / control and verification

With regard to quality control and quality assurance, we refer to Chapter 5.1.7.

5.9.7 Uncertainties and time-series consistency

With regard to the uncertainties relative to the CH_4 and N_2O emissions from digestion of energy crops (digesters and systems for storage of digestion residues), we refer to Table 204 in Chapter 5.1.6 (total uncertainty of the German GHG inventory).

All emissions time series are consistent, since they were calculated with the same method for all years of the report period, and since the input data are also consistent and all data gaps have been filled in (cf. Chapter 5.1.7).

5.9.8 Category-specific recalculations

The emissions time series have been calculated with the same methods for the entire period as of 1990. No comparison with corresponding figures in last year's report (2014 NIR) is possible, since these emissions were not included in that report.

5.9.9 Planned improvements

No improvements are planned at present.

6 LAND USE, LAND USE CHANGES AND FORESTRY (CRF SECTOR 4)

6.1 Overview (CRF Sector 4)

6.1.1 Categories and total emissions and sinks, 1990 - 2013

In the AFOLU-sector sub-category "Land Use, Land Use Changes and Forestry", Germany reports on positive (source) and negative (sink) CO_2 emissions from the carbon pools[87]

- above-ground and below-ground biomass
- dead wood, litter
- organic and mineral soils,

for the land-use categories

- Forest Land (4.A.1)
- Cropland (4.B.1)
- Grassland (4.C.1)
- Wetlands (4.D.1)
- Settlements (4.E.1)

as well as the relevant land-use changes between these use categories (CRF 4.A.2 - 4.E.2). In the category Other Land (4.F), no anthropogenic emissions occur, since the relevant land areas are not used. No land-use changes to Other Land occur, since, by definition, land in use cannot be returned to the category "unused land".

The following are also inventoried:

- CO_2 emissions from
    - wood products (4.G)
    - industrial peat extraction (4.D.1)
- N_2O emissions from
    - drained organic soils in land-use categories 4.A, 4.D, 4.E (emissions from the categories 4.B Cropland and 4.C Grassland are reported under Agriculture in CRF 3.D.a.6)
    - direct (CRF 4.(III)) and indirect (CRF 4.(IV)) emissions from humus mineralisation in mineral soils as a result of land-use changes and / or land cultivation.
    - industrial peat extraction (4.(II))
    - forest fires (4.(V))
- CH_4 emissions from
    - organic soils (4.(II))
    - drainage ditches in organic soils (4.(II))
    - industrial peat extraction (4.(II))
    - forest fires (4.(V))

In reporting on emission/removals of greenhouse gases in the various land-use categories, a distinction is made between areas that, during the report period,

- undergo no land-use changes, and thus are assigned, in unchanged form, to a land-use category ("remaining" categories 4.A.1 - 4.F.1)

[87] CO_2 emissions from forest fires are taken into account implicitly, via carbon-stock changes in Forest Land.

- undergo conversion: From this time on (the time at which they undergo conversion), these areas are reported in the category to which they were converted. Within those land-use categories, the converted areas are then reported in transition categories (4.A.2 - 4.F.2) for a total of 20 years. After spending 20 years in their transition categories, the areas are then added permanently to the relevant final-use categories.

Figure 50, Figure 51 and Figure 52 provide an overview, for the present NIR 2015, of the development over time of greenhouse-gas emissions (sum of CO_2, CH_4 and N_2O emissions, as CO_2 equivalents) in categories 4.A-4.E, differentiated by sub-categories, pools and greenhouse gases. The x axis consists of all the years covered by the report, while the y axis consists of a scale for emissions (positive values) and removals (negative values), expressed in Gg CO_2 equivalents.

The marked changes in emissions in the years 2002 and 2008 result from changes in emission factors for forest biomass and wood use. Wood use increased in the inventory period 2002 through 2008 and then decreased in the period 2008 through 2012 (cf. Chapter 6.4.2.2.1). The time series reflect the changes in forest biomass and the trends in land-use changes (cf. Chapter 6.3.3). The land-use changes have been determined on the basis of data sets for the reference years 1990, 2000, 2005, 2008, 2012 and 2013 (cf. Chapter 6.3). Between the reference years, the land-use changes have been linearly interpolated. As a result, characteristic, average land-use changes emerge for the periods between reference years Table 275). The differences of magnitude in the time series reflect the fact that the periods differ in terms of the magnitude and direction of their land-use changes.

The course of net emissions from 1990 through 2013 shows that, without exception, the sector functioned as a sink during that period. The main reason for this is found in the land-use category Forest Land. The predominant pool is forest biomass, although forest soils also contributed significantly to the sink effect. The sink is offset primarily by emissions from agriculturally used areas in the land-use categories Cropland and Grassland. Over the years, these two categories were a nearly constant source, as a result of continuing high emissions from drained organic soils. The emissions from the land-use category Wetlands, caused mainly by industrial peat extraction and application of horticultural peat (and thus relatively constant), and from the category Settlements, amount to net contributions of only 5.7 % and 8.8 %, respectively, to the sum of positive net emissions. At the same time, the emissions trend from the land-use category Settlements, with an increase of 38.8 %, is highly dynamic and sharply positive. The predominant greenhouse gas is CO_2, and it functions as a strong net sink. On the other hand, releases of methane and nitrous oxide, especially as a result of intensive use of organic soils, are low. Detailed descriptions of the pertinent emissions and their time series are presented in the relevant specialized chapters (Chapter 6.5.1, Chapter 6.6.1, Chapter 6.7.1, Chapter 6.8.1, Chapter 6.9.1 and Chapter 6.10.1).

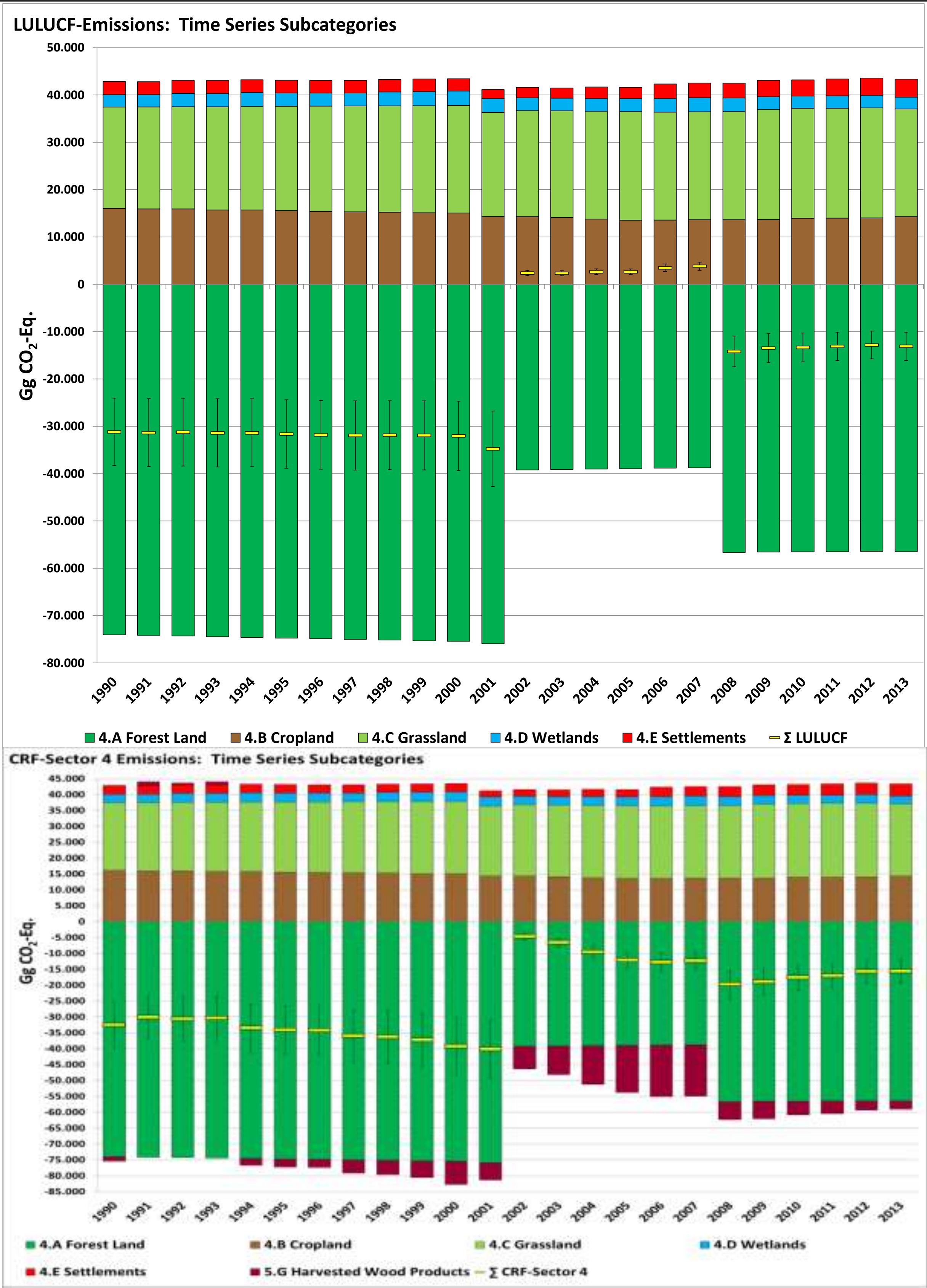

Figure 50: Time series for greenhouse-gas emissions and removals (sum of CO_2, CH_4 and N_2O) [Gg CO_2 equivalents] in the LULUCF sector since 1990, broken down by sub-categories

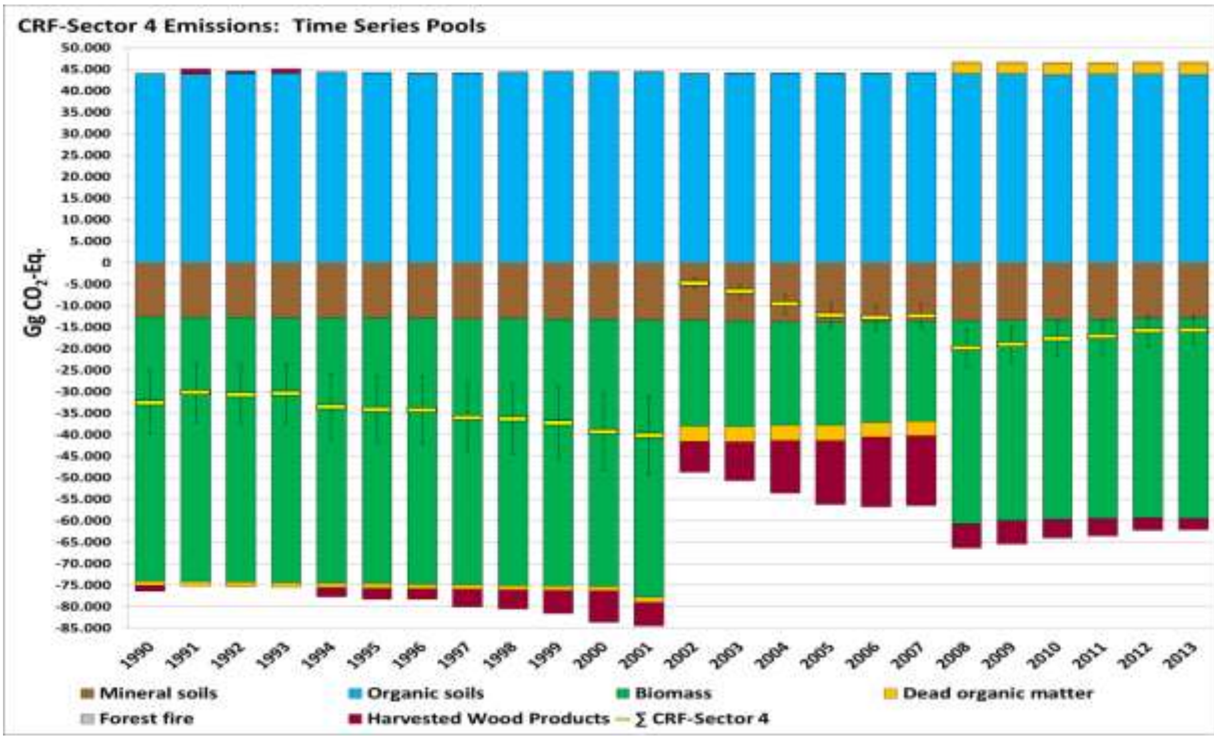

Figure 51: Time series for greenhouse-gas emissions and removals (sum of CO_2, CH_4 and N_2O) [Gg CO_2 equivalents] in the LULUCF sector since 1990, broken down by categories

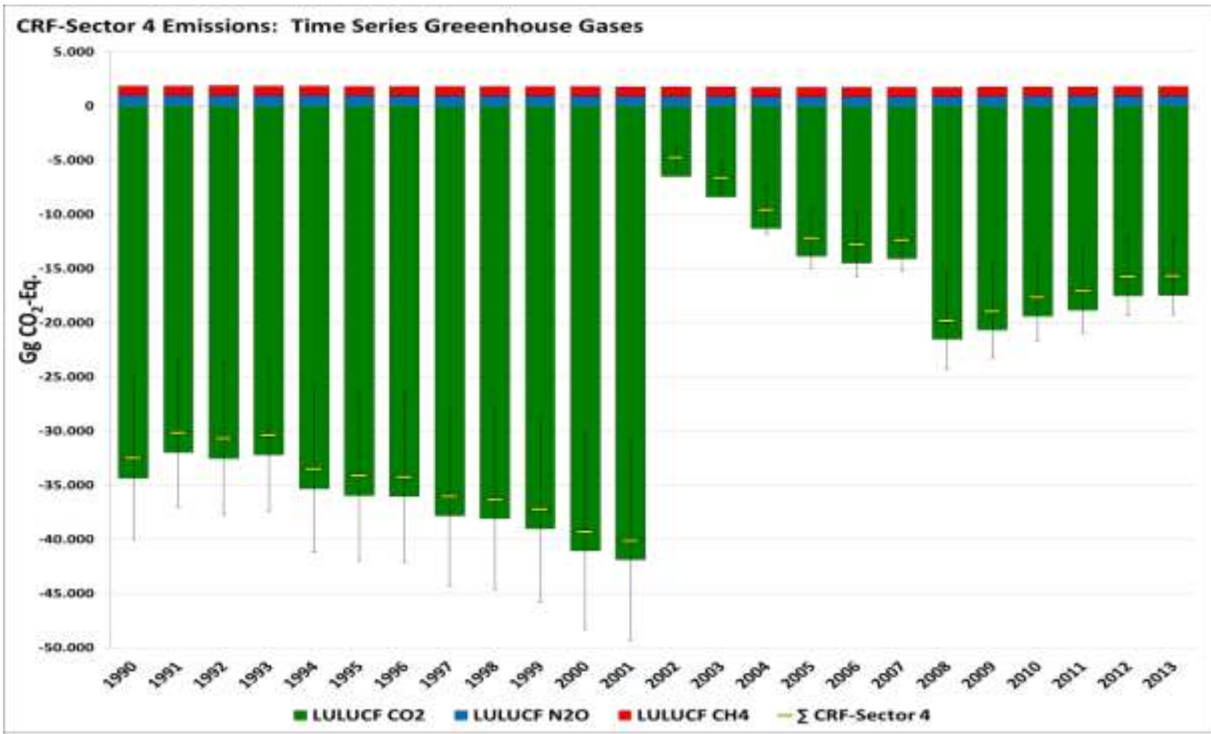

Figure 52: Time series for greenhouse-gas emissions and removals (sum of CO_2, CH_4 and N_2O) [Gg CO_2 equivalents] in the LULUCF sector since 1990, broken down by greenhouse gases (GHG)

The total uncertainty for the German LULUCF inventory is 22.91 %, while that for the trend is 4.82%. The relevant details are presented in the relevant chapters for the individual categories and in Chapter 19.4.4.

6.1.2 Methodological issues

Germany has extensively adopted the land-use-system scheme that the 2006 IPCC Guidelines require for CRF Sector 4. The relevant implementation is outlined in Table 244, and it is described in Chapter 6.2 (cf. also Chapter 6.3).

Table 257: Correlation of the German reporting categories with the IPCC land-use categories

IPCC category	German LULUCF categories
4.A Forest Land	Forest Land
4.B Cropland	Cropland
4.C Grassland	Grassland (in a strict sense) (i.s.s.) Woody grassland
4.D Wetlands	Terrestrial wetlands Peat extraction
4.E Settlements	Settlements
4.F Other Land	Other land
4.G Harvested wood products	

Basic elements of the LULUCF inventory, and the steps required to prepare it

1. **Land-use matrix$_{\text{annual}}$** *[Area_ann]*: Annual calculation of the total areas for the subcategories "final land use" and "land-use change", in each of the categories Forest land, Cropland, Grassland (in a strict sense), Woody grassland, Terrestrial wetlands, Waters, Peat extraction, Settlements and Other land, and, for all time series, with differentiation by mineral and organic soils. The relevant land uses, and the specific areas assigned to them, were explicitly determined for the years 1990, 2000, 2005, 2008 and 2012. For the time periods between those years, the applicable areas were linearly interpolated (cf. Chapter 6.3).
2. **Emission factors for total carbon stocks in a year of a land-use change** *[EF_ann]*: The emission factors for the various pools have been differentiated by land-use categories. They are shown in Table 258 (mineral soils), Table 267 (biomass), Table 263 (forest biomass, deforestation, dead wood and litter) and Chapter (organic soils) . Except in the Forest Land and Cropland categories, carbon stocks per area unit remain constant over time. That means that the same conditions will apply to all parts of one and the same total time series. As a result, carbon stocks change constantly when land use changes.
3. **Carbon-stock changes for annual land-use changes** *[E_ann]* are calculated using the formula **E_ann [Gg C] = EF_ann [Mg C/ha]* Area_ann [kha]**, under the assumption that, in each case, the entire carbon-stock change occurs in the year of the land-use change.
4. **Introduction of a twenty-year transition period** *[Area_20y]*: The relevant areas are shown in the CRF tables Table 273 and Table 274. The land-use-matrix calculation is referenced to 1970, to make it possible to determine land-use-change areas for years prior to the period covered by the report (cf. Chapter 6.3.2). Identified areas on which conversion occurs are assigned to the relevant land-use-change category, in the year in which the land-use change takes place, and they remain in that category, a transition category, for 20 years. Consequently, the areas in the final-use categories are smaller,

in each case, than the corresponding areas in the annual land-use matrix, while the areas in the transition categories are larger than those areas.

5. **Emission factors** *[EF]* **and implied emission factors** *[IEF]* **for the twenty-year transition period** *[IEF_20y]*: These factors are listed in the CRF tables. In a spreadsheet program, annual emission factors are converted into emission factors, and implied emission factors, that are suitable for the land-use matrix areas with 20-year transition periods. The calculations can be checked, step-by-step, in the individual spreadsheet-program worksheets. Conversion of *EF_ann* to *IEF_20y*, following inclusion of the mineral-soil and organic-soil areas for emissions from pools that are taken account of completely in the year of the relevant land-use change, yields adjusted IEFs. Although the absolute emissions remain unchanged as this occurs, the IEFs are influenced by the annual net changes in the areas in the transition categories. The following formulae are used:

   - **Mineral soils**: The entire carbon-stock change as a result of a land-use change is linearly distributed, using the formula *IEF_20y = EF_ann / 20*, over the 20-year transition period; i.e. only one twentieth of the total emissions are added annually.
   - **Organic soils**: The same quantity of CO_2 is emitted each year; in the transition categories, that quantity is identical to the emissions for the final-use category for the new land use; *IEF_20y = EF_ann*.
   - **Net carbon-stock change, carbon-stock increases and decreases in biomass and in dead organic matter, except in the case of land-use changes leading to forest land**: All emissions are taken account of completely in the year of the land-use change, in keeping with the formula *IEF_20y = E_ann / Area_20y*. The emissions that occur in a specific report year are thus adjusted in accordance with the larger area of the relevant transition category.
   - **Net carbon-stock change, carbon-stock increase in biomass and in dead organic matter in connection with land-use changes to forest land**: The entire carbon-stock change resulting from land-use change is calculated with the formula ***IEF_20y = EF_ann***; i.e. the relevant carbon sink is applied to the entire land-use-change area each year.
   - **N_2O from loss of organic matter in mineral soils, as a result of land-use changes to cropland**: The method used is the same as that used for calculation of carbon-stock losses in mineral soils. The entire carbon-stock change as a result of a land-use change is linearly distributed over the 20-year transition period, in keeping with the formula *IEF_20y = E_ann / Area_20y*; i.e. only one twentieth of the total emissions are added each year.

6. **Total carbon-stock changes for areas with twenty-year transition periods** are also calculated, for purposes of the UN Framework Convention on Climate Change, using a spreadsheet program, and in accordance with the following formula: *E_20y [Gg C] = IEF_20y [Mg C/ha]* Area_20y [kha]*

7. **Calculation of CO_2 emissions** for the UNFCCC Inventory, via multiplication of carbon-stock changes by the factor -44/12.

For the present Submission, numerous changes were made in CRF Sector 4, with respect to the previous year's submission. A number of these changes have been made in order to take account of methodological changes, and an expanded reporting scope, resulting via the introduction of the 2006 IPCC Guidelines and the 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (Wetlands Supplement). Others have been made as a result of inventory-improvement measures:

- The activity data set of the reference year has been revised and validated with the help of high-resolution color-infrared aerial photos (CIR data) (this has affected the entire time series for the period 1990 – 2013)
- The current data records of the Basic Digital Landscape Model (Digitales Basis-Landschaftsmodell; Basis-DLM) have been used for the year 2013;
- The map of Germany's organic soils has been implemented (with organic soils defined in keeping with the 2006 IPCC Guidelines (scale: 1: 25,000);
- The time series from peat-production statistics has been corrected;
- The reporting on mineral soils has been expanded: The direct and indirect nitrous oxide emissions from decomposition of organic mineral-soil matter, as a result of land use and land-use change, have been calculated;
- The reporting on organic soils has been expanded to include on-site nitrous-oxide and methane emissions;
- The reporting on organic soils has also been expanded to include methane emissions from drainage ditches;
- New, country-specific CO_2, N_2O and CH_4 emission factors for peat extraction have been introduced;
- New, country-specific CO_2, N_2O and CH_4 emission factors, depending on degree of drainage, have been introduced for organic soils in all land-use categories;
- The emission factors for biomass of perennial crops have been recalculated, to take account of the biomass of short-rotation plantations and tree nurseries;
- The emission factor for the biomass of hedges and field copses has been recalculated, using the complete data records of the research project "Development of methods for determining the biomass of plants, outside of forests, with multiple years of wood growth" ("Methodenentwicklung zur Erfassung der Biomasse mehrjährig verholzter Pflanzen außerhalb von Wäldern"), and the relevant model has been refined;
- The uncertainties of the inventory have been reduced via use of improved emission factors and activity data.

Apart from these changes, the methods, data sources and emission factors used in the previous submission were again used.

6.1.2.1 Greenhouse-gas emissions from mineral soils (4.A to 4.F)

6.1.2.1.1 Carbon

The area of the mineral soils was calculated as the difference between the relevant total areas and the areas covered by organic soils (Chapter 6.1.2).

Changes in carbon and nitrogen stocks in mineral soils are calculated, pursuant to Equation 2.25 in the 2006 IPCC Guidelines (IPCC 2006), as the difference between the relevant stocks prior to, and after, relevant land-use changes. The emission factors have been derived on a country-specific basis. In land-use categories 4.B – 4.F (Cropland, Grassland (in a strict sense), Woody grassland, Wetlands, Settlements and Other land), representative carbon stocks, weighted by area in accordance with parent substrate, soil type and climate region (only topsoils), were defined for mineral soils with depths to 30 cm, differentiated by land use, from usage-differentiated profile data for soils in Germany. The manner in which the relevant values, and their uncertainties, are derived is described Chapter 19.4.2. The values for forest soils have been obtained from complete-coverage inventories of forest soils (cf. Chapter 6.4.2.5.3). The reporting on mineral soils thus applies a Tier 2 method.

In the framework of the Forest Soil Inventory, an annual carbon-stock change of 0.41 ± 0.11 Mg C ha^{-1} a^{-1} was determined for category 4.A.1, Forest Land remaining Forest Land (cf. Chapter 6.4.2.5.3 and Chapter 19.4.2.1). On an annual basis, that quantity is added to the previous year's stocks and reported as a removal.

For mineral soils with no use change, in land-use sub-categories 4.B, 4.C, 4.D, 4.E and 4.F, it is assumed that the pertinent carbon inputs into the soil and carbon extractions from the soil are equal in size, so that the systems are in balance. The reasons for this assumption are described in Chapter 6.5.2.3 and Chapter 6.6.2.3.

The category Grassland (4.C 1) has two sub-categories: grassland (in a strict sense), and grassland areas with woody plants and shrubs that do not fall within the Forest land category as it is defined. The transition areas between those two sub-categories are treated like land-use changes.

The category Wetlands (4.D.1) has three sub-categories: terrestrial wetlands, peat-extraction areas (only as a non-transfer category) and waters (flooded land). The area transitions between those two sub-categories are treated like land-use changes. Mineral soils occur only in the two sub-categories "terrestrial wetlands" and "waters". No carbon-stock changes are applied in connection with land-use changes from and to waters. As a result, no carbon-stock changes in mineral soils occur in connection with land-use changes between the relevant sub-categories (NO).

For each land-use-change category, the carbon-stock changes in mineral soils as a result of land-use changes are calculated as the difference between the carbon stocks of the non-transfer category and the carbon stocks of the original category. Since the carbon stocks in forest soils (4.A) change annually, the relevant inventory calculations are based on the valid annual values for all years in question. Pursuant to IPCC Default (IPCC 2006), the total changes are linearly distributed over a period of 20 years. The sum of all carbon-stock changes resulting from land-use changes in Germany's mineral soils is calculated, for a 20-year period, as follows:

$$\Delta C = \sum_{n=1}^{7} \left(C_{final} - C_{initial}\right)$$

ΔC:	Change in carbon stocks as a result of land-use changes in mineral soils of an IPCC land-use category [Mg C $(20*a)^{-1}$]
C_{final}:	Final soil-carbon stocks [Mg C]
$C_{initial}$:	Initial soil-carbon stocks [Mg C]
n	Transfer categories

The carbon stocks of mineral soils in the various land-use categories, and the carbon-stock changes derived from those stocks and used as emission factors, are shown for 2013 in Table 258; the pertinent derivations are described in Chapter 19.4.2.

Table 258: Mean carbon stocks in Germany's mineral soils, by land use [Mg C ha^{-1}], and derived (e.g. therefrom) carbon-stock changes, as a result of land-use changes, for 2013

Mean carbon stocks in Germany's mineral soils in 2013								
	Forest land	**Crop-land**	**Grassland**	**Woody grassland**	**Terrestrial wetlands**	**Waters**	**Settlements**	**Other land**
[Mg C ha^{-1}]	*64.67*	60.03	77.43	73.18	74.00		58.67	55.60
Carbon-stock change in 20 years [Mg C ha^{-1} (20 a)$^{-1}$]								
Initial\final	**Forest land**	**Crop-land**	**Grassland (in a strict sense)**	**Woody grassland**	**Terrestrial wetlands**	**Waters**	**Settlements**	**Other land**
Forest land		*-4.64*	*12.76*	*8.51*	*9.33*	0	*-6.00*	NO
Cropland	*4.64*		17.40	13.15	13.97	0	-1.35	NO
Grassland (in a strict sense)	*-12.76*	-17.40		-4.25	-3.43	0	-18.76	NO
Woody grassland	*-8.51*	-13.15	4.25		0.82	0	-14.51	NO
Terrestrial wetlands	*-9.33*	-13.97	3.43	-0.82		0	-15.32	NO
Waters	0	0	0	0	0		0	NO
Settlements	*6.00*	1.35	18.76	14.51	15.32	0		NO
Other land	*9.07*	4.42	21.83	17.58	18.39	0	3.07	

Values in italics: Changing from year to year

Negative: Carbon losses; positive: Carbon sequestration; NO: not occurring

To take account of the 20-year transition period, the total stock change for each transition category in question (EF_ann, cf. Table 258) is divided by 20 (cf. also Chapter 6.1.2). This yields the implied emission factors for the transition categories (IEF_20y; cf. Table 259). In the case of land-use changes to and from Forest Land, and because carbon stocks in mineral forest soils change from year to year, an implied emission factor has to be derived for each transition category. Such IEF, which vary from year to year, are obtained in each case from the contributions of the land-use changes of the 20 previous years, weighted by emissions. The emissions are calculated as the product of IEF_20y and the areas of the 20-year transition categories (cf. Chapter 6.1.2).

Table 259: Emission factors [Mg C ha^{-1} a^{-1}] for determination of annual carbon-stock changes in Germany's mineral soils, following land-use changes, for the year 2013

Emission factors$_{\text{mineral soils}}$ [Mg C ha^{-1} a^{-1}] for the year 2013								
Initial\final	**Forest land**	**Cropland**	**Grassland (in a strict sense)**	**Woody grassland**	**Terrestrial wetlands**	**Waters**	**Settlements**	**Other land**
Forest land		*0.025*	*0.871*	*0.598*	*0.645*	0	*-0.097*	NO
Cropland	*0.0002*		0.870	0.658	0.699	0	-0.068	NO
Grassland (in a strict sense)	*-0.850*	-0.870		-0.213	-0.172	0	-0.938	NO
Woody grassland	*-0.630*	-0.658	0.213		0.041	0	-0.725	NO
Terrestrial wetlands	*-0.697*	-0.699	0.172	-0.041		0	-0.766	NO
Waters	0	0	0	0	0		0	NO
Settlements	*0.082*	0.068	0.938	0.725	0.766	0		NO
Other land	*0.194*	0.221	1.091	0.879	0.920	0	0.154	

Values in italics: Changing from year to year

Negative: Carbon losses; positive: Carbon sequestration; NO: not occurring

The area of the mineral soils in the transition categories was calculated as the difference between the relevant total areas and the areas covered by organic soils (Chapter 6.1.2.1).

6.1.2.1.2 Nitrous oxide

The direct (CRF Table 4.III) and indirect (CRF Table 4.IV) N_2O emissions tied to losses of organic soil substance resulting from land-use changes and land cultivation have been determined in keeping with the 2006 IPCC Guidelines. To that end, the carbon-stock changes determined for the various individual land-use-change areas were divided by the mean, area-weighted C/N ratios for the pertinent soils, in order to obtain the absolute changes in soil nitrogen stocks (Equation 11.8 in the 2006 IPCC Guidelines). The C/N ratios were derived from the estimated profile data of the BÜK 1000 n 2.3 soil map (BGR 2011).

For determination of the direct emissions, the absolute N-stocks differences were multiplied by the IPCC default value of 0.01 kg N_2O-N (kg N)$^{-1}$, in keeping with Equation 11.1 in the 2006 IPCC Guidelines. The so-determined N_2O emissions are listed in CRF Table 4.III, while the relevant emission factors are listed in Table 260 and the uncertainties are presented in Chapters 6.6.3, 6.7.3, 6.8.3 and 6.9.3.

For estimation of the indirect nitrous oxide emissions, the N-stocks differences pursuant to Equation 11.10 of the 2006 IPCC Guidelines were multiplied by the default factors $Frac_{Leach-(H)}$ (0.3 kg N_2O-N (kg N)$^{-1}$) and EF_5 (0.0075 kg N_2O-N (kg N)$^{-1}$) (2006 IPCC Guidelines). The emission factors for the indirect nitrous oxide emissions, for the year 2013, are listed in Table 261. They also listed, along with the pertinent uncertainties, in Chapters 6.6.3, 6.7.3, 6.8.3 and 6.9.3. The figures presented also include the results entered in CRF Table 4.IV.

The nitrous oxide emissions are also subject to transition-time considerations; like the carbon-stock changes, they are distributed over 20 years.

Table 260: Emission factors for direct nitrous oxide emissions [kg N_2O ha^{-1} a^{-1}] caused by losses of organic matter from Germany's mineral soils, following land-use changes, for the year 2013

	Emission factors$_{mineral\ soils}$ [kg N_2O ha^{-1} a^{-1}] for the year 2013							
Initial\final	**Forest land**	**Cropland**	**Grassland (in a strict sense)**	**Woody grassland**	**Terrestrial wetlands**	**Waters**	**Settlements**	**Other land**
Forest land		*0.029*	*0*	*0*	*0*	0	*0.078*	NO
Cropland	*0.015*		0	0	0	0	0.087	NO
Grassland (in a strict sense)	*1.053*	1.078		0.263	0.213	0	1.162	NO
Woody grassland	*0.827*	0.845	0		0	0	0.932	NO
Terrestrial wetlands	*0.710*	0.711	0	0.042		0	0.780	NO
Waters	0	0	0	0	0		0	NO
Settlements	*0.018*	0	0	0	0	0		NO
Other land	*0*	0	0	0	0	0	0	

Values in italics: Changing from year to year
Positive: Nitrous oxide emissions

Table 261: Emission factors for indirect nitrous oxide emissions [kg N_2O ha^{-1} a^{-1}] caused by losses of organic matter from Germany's mineral soils, following land-use changes, for the year 2013

	Emission factors$_{mineral\ soils}$ [kg N_2O ha^{-1} a^{-1}] for the year 2013							
Initial\final	**Forest land**	**Cropland**	**Grassland (in a strict sense)**	**Woody grassland**	**Terrestrial wetlands**	**Waters**	**Settlements**	**Other land**
Forest land		*0.007*	*0*	*0*	*0*	0	*0.018*	NO
Cropland	*0.015*		0	0	0	0	0.019	NO
Grassland (in a strict sense)	*0.237*	0.243		0.059	0.048	0	0.261	NO
Woody grassland	*0.186*	0.190	0		0	0	0.210	NO
Terrestrial wetlands	*0.160*	0.160	0	0.009		0	0.175	NO
Waters	0	0	0	0	0		0	NO
Settlements	*0.004*	0	0	0	0	0		NO
Other land	*0*	0	0	0	0	0	0	

Values in italics: Changing from year to year
Positive: Nitrous oxide emissions

6.1.2.2 Greenhouse gas emissions from drained organic soils (4.A to 4.F; 4.(II))

CO_2, N_2O and CH_4 emissions from organic soils are reported in the land-use categories Forest land, Cropland, Grassland (in a strict sense), Woody grassland, Terrestrial wetlands (industrial peat extraction) and Settlements (N_2O from drained organic soils is reported under Cropland and Grassland in CRF Sector 3.D). Reporting also covers methane emissions from drainage ditches, as well as carbon losses in connection with dissolved organic matter (DOM). The majority of organic soil areas in Germany consists of drained areas.

The emissions are calculated by multiplying the bog areas per sub-category by pertinent use-specific emission factors. For land-use changes, the emission factor for the final category is used right away:

$$EC_{orgsoil} = \sum_{n=1}^{7} (A_n * EF_n)$$

$EC_{orgsoil}$: Carbon emissions from organic soils in a land-use category [Gg C]
A_n: Bog area subject to a certain land use [kha]
EF_n: Land-use-specific emission factor [Mg C ha^{-1} a^{-1}]
n: Transition categories or "remaining" categories

In the present submission, highly detailed maps showing the positions and drainage status of organic soils are being used for the first time. These maps have been made possible via extensive research carried out over the past few years. In addition, the submission makes use of extensive measurement data on greenhouse-gas emissions from organic soils in Germany that have been generated, using standardised measurement protocols, in the "Organic Soils" ("Organische Böden") project, a collaborative research project of the Johann Heinrich von Thünen Institute (Federal Research Institute for Rural Areas, Forestry and Fisheries) (www.organische-boeden.de), and in predecessor projects (a small quantity of the data was obtained from the relevant national literature). The database for the activity data and emission factors, and the relevant derivations, are in keeping with IPCC Tier 3. In the interest of transparency, and in order to maintain consistency with other activity data and carbon pools, the database and the derivations have been turned into a national Tier 2 method for the inventory.

6.1.2.2.1 Activity data (3.D, 4.A- 4.E; 4.(II))

Under commission to the Thünen Institute, an "Organic Soils Map" ("Karte organischer Böden") (Parametrized area data on the organic soils in Germany) was prepared that is fully in keeping with the IPCC definition of organic soils (HUMBOLDT-UNIVERSITÄT 2013):

- Spatial resolution / scale: heterogenous, for process-related reasons, ~1:10,000 – 1:200,000; grid width 25 m.
- Temporal resolution: regionally varying, depending on the database involved (from the beginning of of the 20th century to the present).
- Data sets: in close cooperation with the relevant authorities of the German Länder (states), and in an approach designed to be as comprehensive as possible, and to obtain the highest-possible resolution, the data sets were prepared by integrating and harmonizing existing soil data, bog cadastres and data records from geological, silvicultural and agricultural mappings.
- Data selection (minimal criterion): In keeping with the "Bodenkundliche Kartieranleitung" soil mapping instructions (KA 5, ARBEITSGRUPPE BODEN 2005) and the IPCC 2006 instructions for reporting on organic soils, among map sheets with legend units based on digital (vector-form) outset data, map data were chosen that primarily describe soils with a 9 % minimum content of organic carbon (15 % organic soil matter) in a mixed sample of the upper 20 cm.

The new organic-soils area has a total area of 1.825 million ha. The new organic soils map supplants the previously used overview soil map, which was drawn to a coarse scale of 1:1,000,000 (BGR 1997), and which did not include any shallow peat soils or peats mixed with mineral soils (old total area: 1.725 million ha). The area allocations in the new organic soils map are much more precise than those in the old map, and the area proportions of the various land-use categories have changed as a result. Grassland in the strict sense is now far and away the predominant use, while Cropland is much less common than had previously been assumed. Table 262 shows the organic soils areas, by land-use categories, along with the applicable drained-area fractions, for the year 2013.

Table 262: Organic soils areas, by land-use categories, and drained-area fractions, for the year 2013 (3.D, 4.A- 4.E; 4.(II))

	Areas of land with organic soils [kha]	**Drained fraction [%]**
Forest land	336	88
Cropland	356	100
Grassland (in a strict sense)	967	93
Woody grassland	21	88
Terrestrial wetlands	37	77
Waters	20	0
Peat extraction	20	100
Settlements	68	100
Other land	2	0
∑	**1825**	

The drained fractions of organic soils areas, by land-use categories, were derived from the regional distribution of water levels in Germany's organic soils (BECHTOLD et al. 2014). Those levels have been obtained, inter alia, from the map of organic soils and from long-term measurements of water levels in organic soils. The drained fraction of organic soils consists of those areas that have an average annual water level lower than 0.1 m below ground level.

For determination of CH_4 from drainage ditches, a ditch-area fraction (Fracditch) of 1.3 % was determined, using the ATKIS-Basis-DLM Basic Digital Landscape Model. That figure applies for all land-use categories.

6.1.2.2.2 Emission factors for greenhouse gases from drained organic soils, in all land-use categories (3.D, 4.A- 4.E; 4(II))

The emission factors have been developed in keeping with the guidelines in the 2013 IPCC Wetlands Supplement (IPCC 2014). The emission factors for CO_2 from soils (CO_2-C on-site), CH_4 from soils (CH_{4_land}) and N_2O were developed from national annual measurements. For CO_2 from dissolved organic carbon (CO_2-C_{DOC}) and CH_4 from drainage ditches (CH_{4_Ditch}), the default values in the 2013 IPCC Wetlands Supplement (IPCC 2014) have been used.

CO_2 from soils (CO_2-$C_{on\text{-}site}$):

The database consists of representative, quality-checked, national annual measurements (208 measurement years, 95 sites, 13 different bog areas) obtained on areas with an average annual water level of 0 cm or more below ground level (no overflow). This data set exhibits a linear correlation, across all land-use categories, with average annual water levels. Via linear regression, it is thus possible, for each 25 x 25 m pixel of the map of the regional distribution of water levels in Germany's organic soils (BECHTOLD et al. 2014), to calculate CO_2 emissions from soil (CO_2-$C_{on\text{-}site}$) with an average annual water level lower than 0.1 m below ground level. The uncertainty of the water-level map was taken into account in the uncertainties calculation. From the map of the relevant results, the average value and the 95th percentile value following the uncertainties calculation were derived as emission factors. Table 263 provides an overview of the national emission factors. In each case, it shows both the nationally derived portion of the CO_2 emission factor and the fully aggregated emission factor as used in the inventory.

Table 263: Emission factors for CO_2-$C_{organic\_drained}$ from drained organic soils, in all land-use categories (4.A- 4.E; 4(II))

Land use	NIR 2015 Soil-CO_2-C_{onsite} Mg CO_2-C ha^{-1} a^{-1}	NIR 2015 CO_2-$C_{total\_organic\_drained}$ Mg CO_2-C ha^{-1} a^{-1}	NIR 2014 CO_2-$C_{total\_organic\_drained}$ Mg CO_2-C ha^{-1} a^{-1}	IPCC Wetlands Supplement CO_2-$C_{total\_organic\_drained}$ Mg CO_2-C ha^{-1} a^{-1}
Forest land / Woody grassland	IPCC	2.9 (2.3 -3.6)	0.68 (0.41 - 1.23)	2.9 (2.3 - 3.6)
Cropland	7.8 (4.1 - 4.9)	8.1 (4.4 - 9.5)	11 (5.5 - 16.5)	8.2 (6.8 - 9.7)
Grassland, Settlements	7.1 (3.0 - 9.2)	7.4 (3.3 - 9.5)	5 (2.5 - 7.5)	6.4 (5.3 - 7.6)
Terrestrial wetlands	6.2 (2.3 - 9.2)	6.5 (2.5 - 9.5)	0	/
Peat-extraction areas	1.2 (1.2 - 1.4)	1.6 (1.5 - 1.8)	0.2 (0 - 0.63)	3.1 (1.4 - 4.5)

CH_4 from soil (CH_{4_land}):

The database consists of representative, quality-checked, national annual measurements (197 measurement years, 97 sites, 15 different bog areas) obtained on areas with an average annual water level of 0 cm or more below ground level (no overflow). The emission factor was derived in a manner similar to that used for the emission factor for CO_2 from soil (CO_2-C on-site). Because methane emissions grow exponentially with rising water levels, an exponential function was used. Land-use-dependent exponential functions for Forest Land, Grassland and Wetlands were developed. Cropland and peat-extraction areas proved to be too dry for achievement of any correlation with water levels. For this reason, the average values of the measurements were used for these two land-use categories. Table 264 provides an overview of the national emission factors. In each case, it shows both the nationally derived portion of the CH_4 emission factor and the fully aggregated emission factor as used in the inventory.

Table 264: Emission factors for $CH_{4\text{-organic}}$ from drained organic soils, in all land-use categories (4.A- 4.E; 4(II))

Land use	NIR 2015 CH_{4_land} kg CH_4 ha^{-1} a^{-1}	NIR 2015 $CH_{4\_organic\ (land+ditch)}$ kg CH_4 ha^{-1} a^{-1}	IPCC Wetlands Supplement CH_{4_land} kg CH_4 ha^{-1} a^{-1}
Forest land / Woody grassland	3.7 (-2.1 - 70)	6 (0.3 - 72)	2.5 (-0.6 - 6)
Cropland	11.4 (-2.7 - 73)	26 (8.8 - 88)	0 (-2.8 - 3)
Grassland, Settlements	10.4 (3.6 - 69)	23 (12 - 81)	16 (2.4 - 29)
Terrestrial wetlands	17 (1.5 - 150)	20 (4.1 - 151)	/
Peat-extraction areas	4.2 (-0.4 - 13)	11 (3.9 - 22)	6.1 (1.6 - 11)

N_2O:

The database consists of representative, quality-checked, national measurements that cover at least a year in each case (94 sites, 20 different bog areas) and were obtained on areas with an average annual water level of 0.1 m or more below ground level (no overflow). The national database is part of the European data records in LEPPELT et al. (2014). Since no functional interrelationships were identified, the average measurement values for the various land-use categories were defined as the emission factors. Table 265 provides an overview of the national emission factors for N_2O.

Table 265: Emission factors for N_2O from drained organic soils, in all land-use categories (3.D, 4.A- 4.E; 4(II))

Land use	NIR 2015 kg N_2O-N ha^{-1} a^{-1}	IPCC Wetlands Supplement kg N_2O-N ha^{-1} a^{-1}
Forest land / Woody grassland	1.8 (0.1 - 5.3)	2.8 (-0.6 - 6.1)
Cropland	10.7 (1.6 - 41.4)	13 (8.2 - 18)
Grassland, Settlements	2.7 (0 - 8.9)	8.2 (4.9 - 11)
Terrestrial wetlands	0.4 (-0.1 - 1.6)	1.6 (0.6 - 2.7)

6.1.2.2.3 Implied emission factors (IEF) for greenhouse gases from organic soils (4.A- 4.E; 4(II))

In the framework of inventory preparation, the emissions from organic soils are calculated with implied emission factors – including specific factors for each greenhouse gas and for each land-use category. The emission factors shown in Chapter 6.1.2.2.2 apply for drained organic soils. In determination of emissions from a specific land-use category, undrained, wet areas also have to be taken into account, however, and thus the IEF for peat-extraction areas also has to take account of emissions from peat that has been extracted and applied. This perspective leads to the implied emission factors shown in Table 266 as the factors for calculation of greenhouse-gas emissions from organic soils. In some cases, these factors differ considerably from the factors presented in Chapter 6.1.2.2.2.

Table 266: Implied emission factors for CO_2-C, CH_4 and N_2O-N from organic soils (4.A- 4.E; 4(II))

Land use	CO_2-C Mg CO_2-C ha^{-1} a^{-1}	CH_4 kg CH_4 ha^{-1} a^{-1}	N_2O-N kg N_2O-N ha^{-1} a^{-1}
Forest land	-2.61	5.40	1.62
Cropland	-8.10	26.00	-
Grassland	-6.82	21.21	-
Woody grassland	-2.61	5.40	1.62
Terrestrial wetlands	-2.21	6.81	0.14
Peat-extraction areas	-29.48	11.19	0.85
Settlements	-7.40	23.00	2.70

6.1.2.3 Biomass (4.B to 4.F)

In the framework of German inventory preparation, the LULUCF categories 4.B – 4.F include only carbon dioxide (CO_2) removals and emissions resulting from land-use changes between the eight reported land-use categories. In the process, removals and emissions of CO_2 are determined via the relevant carbon-stock changes, on the basis of national data, and separately for above-ground and below-ground biomass. In each case, a carbon-stock change takes place completely in the year of the relevant land-use change (cf. also Chapter 6.1.2). For the non-transfer ("remaining") categories of cropland, grassland, woody grassland, wetlands and settlements, no carbon-stock changes are listed, since the carbon fluxes in those categories are assumed to be in balance with the relevant biomass. The reasons for this assumption are described in Chapters 6.6.2 and 6.7.2.

The carbon-stock changes in biomass are estimated by subtracting the biomass carbon stock before the land-use conversion from the stock after the conversion, with reference to the area affected by the change (in keeping with Equation 2.16, 2006 IPCC Guidelines):

$$\Delta C_{Bio} = \sum_{n=1}^{7} \left(A_n * EF_{final} - A_n * EF_{initial} \right)$$

ΔC_{Bio}: Change in the biomass carbon stock for a given land-use category [Mg]
A_n: Area on which the land-use change has occurred [ha]
EF_{final}: Plant-specific biomass carbon stock [Mg ha^{-1}]
$EF_{initial}$: Plant-specific biomass carbon stock [Mg ha^{-1}]
n: Transition categories

The biomass stocks are calculated in keeping with the gain-loss method (2006 IPCC Guidelines). Chapter 6.3 provides a description of the relevant activity-data identification, while derivation of country-specific emission factors and their uncertainties is described in Chapter 19.4.3 and in the chapters for the individual land-use categories. The reporting on biomass is equivalent to a Tier 2 method.

The biomass carbon stocks on cropland vary annually and are calculated for each year on the basis of harvest statistics. Therefore, the same data sources and algorithms are used as are used for calculating crop residues in CRF Sector 3.D. The emission factors in Table 267 are obtained, in each case, as the difference between the biomass stocks under the new land-use category and the stocks under the old land-use category. With respect to Cropland, the factors differ from the corresponding factors of the previous year, since the annual changes in carbon stocks of annual crops, and use of newly calculated, improved emission factors for perennial crops, led to changes in the affected transfer categories.

Table 267: Emission factors [Mg C ha^{-1} a^{-1}] for determination of carbon-stock changes in the year of the conversion, in above-ground and below-ground biomass, by type of land-use change, for the year 2013

Mean carbon stocks in above-ground and below-ground biomass								
	Forest land[88]	Cropland	Grassland (in a strict sense)	Woody grassland	Terrestrial wetlands	Waters	Settlements	Other land
[Mg C ha-1]	54.66	7.52	6.69	43.16	18.85	0	12.46	0
2013 emission factors for biomass [Mg C ha^{-1} a^{-1}]								
Initial\final	**Forest land[89]**	**Cropland[90]**	**Grassland (in a strict sense)[90]**	**Woody grassland[90]**	**Terrestrial wetlands[90]**	**Waters[90]**	**Settlements[90]**	**Other land[90]**
Forest Land		-47.14	-47.97	-11.50	-35.81	-54.66	-42.20	NO
Cropland	3.40		-0.84	35.64	11.32	-7.52	4.94	NO
Grassland (in a strict sense)	3.14	0.84		36.48	12.16	-6.69	5.78	NO
Trees and shrubs	2.33	-35.64	-36.48		-24.32	-43.16	-30.70	NO
Terrestrial wetlands	3.64	-11.32	-12.16	24.32		-18.85	-6.38	NO
Waters (in CRF: Waters)	3.64	7.52	6.69	43.16	18.85		12.46	NO
Settlements	3.55	-4.94	-5.78	30.70	6.38	-12.46		NO
Other land	3.64	7.52	6.69	43.16	18.85	0	12.46	

Remark: The carbon stocks for forest land and cropland are chronologically variable (values in italics), while those for the other land-use categories are constant

For calculation relative to conversion of forest land into other land uses (deforestation), the average value determined for deforestation areas in Germany, in the National Forest Inventories of 2002 and 2012, was used as a basis for the relevant reporting years. For the relevant methods and value derivation, cf. Chapter 6.4.2.2. New values for dead wood were also determined via the BWI 2012.

Table 268: Time series for mean carbon stocks in phytomass of deforestation areas [Mg C ha^{-1}]

Year	Phytomass – carbon [Mg ha^{-1}] (EF 1)					
	Biototal	Bioabove	Biobelow	Litter	Dead wood	Σ deforestation
1990	28.93	24.53	4.39	19.00	1.88	49.81
1991	28.93	24.53	4.39	18.99	1.88	49.80
1992	28.93	24.53	4.39	18.98	1.88	49.79
1993	28.93	24.53	4.39	18.96	1.88	49.77
1994	28.93	24.53	4.39	18.95	1.88	49.76
1995	28.93	24.53	4.39	18.94	1.88	49.75
1996	28.93	24.53	4.39	18.93	1.88	49.74
1997	28.93	24.53	4.39	18.91	1.88	49.72
1998	28.93	24.53	4.39	18.90	1.88	49.71
1999	28.93	24.53	4.39	18.89	1.88	49.70
2000	28.93	24.53	4.39	18.88	1.88	49.69
2001	28.93	24.53	4.39	18.86	1.88	49.67
2002	54.66	46.48	8.18	18.85	1.82	75.33
2003	54.66	46.48	8.18	18.84	1.82	75.31
2004	54.66	46.48	8.18	18.83	1.82	75.30
2005	54.66	46.48	8.18	18.81	1.82	75.29
2006	54.66	46.48	8.18	18.80	1.82	75.28
2007	54.66	46.48	8.18	18.79	1.82	75.26
2008	54.66	46.48	8.18	18.78	1.99	75.42
2009	54.66	46.48	8.18	18.76	1.99	75.41
2010	54.66	46.48	8.18	18.75	1.99	75.39
2011	54.66	46.48	8.18	18.74	1.99	75.38
2012	54.66	46.48	8.18	18.73	1.99	75.37
2013	54.66	46.48	8.18	18.71	1.99	75.36

[88] Carbon stocks of deforestation areas

[89] Annual carbon-stock change over 20 years

[90] One-time carbon-stock change

The uncertainty for the tree biomass is 24.95 % (half of the 95 % confidence interval). The distribution is normal. This also applies for the values for the dead organic matter; for dead wood, half of the 95 % confidence interval is 56.76 %, while for litter it is 3.15 %. The uncertainties for the emission factors listed in Table 267 are set forth in the chapters for the relevant land-use categories (Chapter 6.4.3, Chapter 6.5.3, Chapter 6.6.3, Chapter 6.7.3, Chapter 6.8.3 and Chapter 19.4.3).

On-site burning of biomass is prohibited by law in Germany (Art. 3 German Ordinance on direct payments (DirektZahlVerpflV); Federal Law Gazette (BGBl) 2004) and thus is not reported. In the CRF tables, NO (not occurring) is entered for that category.

Emissions from dead organic matter are reported only for land-use changes from forest land to one of the categories 4.B – 4.E. In the land-use-change categories 4.B – 4.E, emissions from dead organic matter are included with emissions from living biomass, since estimates of emissions from living biomass are always oriented to entire plants. To prevent double counting, therefore, in these transfer categories, emissions from dead organic matter are marked IE (included elsewhere) in the CRF tables. In category 4.F, NO (not occurring) is used, since, by definition, the areas in this category have no vegetation cover.

6.1.3 Quality assurance and control

General and category specific quality control and a quality assurance have been carried out by source-category experts and the Single National Entity, according to the QSE-Handbook. In the process, detailed checklists were used, and individual checks carried out, for review and documentation of the results in keeping with the quality management guidelines of the Thünen institute (2012). The TI checklists, along with other documents of importance for quality control, are added to the inventory description that is archived by the Single National Entity.

6.1.3.1 The Thünen Institute's quality management for emissions inventories

The Thünen Institute's quality management for emissions-inventory preparation has been developed in conformance with the IPCC guidelines and the QSE (Chapter 1.6.1). The framework for the quality management, and the process for carrying it out, are described in detail in the relevant concept (BMEL, 2012) and in the provisions for implementation of the concept (TI, 2012). All pertinent documents and data are added to the inventory description that is archived by the Single National Entity. The requirements and procedures set forth by the provisions for implementation of the concept were fully complied with. The following section describes the special additional quality controls carried out for the present Submission.

6.1.3.2 Input data, calculation procedures and emissions results

In a first step, the land-use matrix was checked for quality and then approved for emissions calculation. Such checking covered the decision trees and the results of the annual land-use matrix and of the 20-year transition period. The following section lists key test criteria, for the land-use matrix, that were applied in this year's tests. These criteria exceed the requirements set forth by the provisions for implementation of the concept. They apply for the entire land-use matrix and for the two sub-matrixes for mineral soils and organic soils:

- The national area is constant.
- The national area is the same as that used in the previous year.

- The areas of the land-use categories are the same, or almost the same, as the corresponding areas used in the previous year; if there are any discrepancies, they can be explained.
- The areas and area trends are consistent with the relevant statistical data; if and where they are not consistent, the discrepancies can be explained.
- The sums of the total areas, consisting of remaining areas and areas with land-use changes, are correct.
- Other land areas have remained the same or have decreased; no land-use changes to "Other land" have occurred.
- Peat-extraction areas have been listed separately.
- Conistency between LULUCF and KP-LULUCF is assured with regard to forest-land areas and afforestation/reforestation/deforestation (ARD) areas.

The emissions calculations have been carried out using the quality-assured land-use matrix. Emissions calculations relative to annual land-use changes, and to the transition period, are gradually being carried out in Excel tables, using the area data and emission factors / implied emission factors (IEF). The tables have been reviewed with regard to:

1. Correctness of calculations
2. Consistency of time series
3. Consistency with the calculations of the previous year.

The following section lists the criteria used for this year's tests. These criteria exceed the requirements set forth by the provisions for implementation of the concept.

Emission factors:

- The calculations of the emission factors and implied emission factors (IEF) are correct.
- The time series for the emission factors is consistent; any changes from year to year can be explained.
- The emission factors are the same as those of the previous year, except in cases in which data and methods have changed; any new emission factors are plausible. Any differences with respect to those of the previous year can be explained and have been completely documented.
- Uncertainties have been correctly reported and are consistent with those of the previous year.
- Data consistency between the LULUCF and KP-LULUCF frameworks is assured.

Calculations:

- The basic calculations, and the calculations for the annual land-use changes and the transition period, are correct.
- The overview tables, which serve as the basis for the CRF tables and the text, are correct.
- The emissions results are consistent with those of the previous year; any discrepancies can be explained as the result of use of new data and methods.
- Consistency between the LULUCF and KP-LULUCF frameworks is assured with regard to calculations.

Results of quality controls:

1. All calculations were correct.

2. The time series are consistent. Any major year-to-year changes result solely from the periodicity of data and from linear interpolation between pertinent periods.
3. No unexplainable outliers were found in the relative differences with regard to the emissions of the previous year. All changes with respect to the previous year have been correctly documented and are included in the National Inventory Report.

After the relevant activity data and implied emission factors (IEF) were entered into the Central System of Emissions (CSE) database, the emissions as calculated in the CSE were compared against the emissions results that had been obtained with the Thünen Institute's own inventory model. All quality control steps and their results are fully recorded in the inventory description that is archived by the Single National Entity.

6.1.3.3 Verification

The results relative to IEF, differentiated by C pools and land-use categories, have been compared with those of neighbouring countries. Details relative to such comparison are provided in the relevant sub-chapters.

6.1.3.4 Reviews and reports

In September 2010, an In-Country Review was carried out. Its most important result was that the methods used for the land-use matrix and carbon-stock changes in mineral soils were not accepted. Germany has been successively changing those methods. In the 2012 Submission, it used the changed methods throughout, for the first time, and introduced 20-year transition periods following land-use changes, for all land-use categories. In addition, the data frameworks, methods and national circumstances relative to national emission factors were described in considerably greater detail, and in a more structured manner, in order to enhance the inventory's transparency. All data and documents are centrally archived in the GHG Wiki of the Thünen Institute and the Single National Entity. The recommendations from the Centralized Reviews of the submissions of the years 2011 through 2014 were followed. For example, additional sub-categories have been included for the land-use categories Grassland and Wetlands. The explanations provided for the calculations relative to forest biomass and litter pools (which explanations the reviewers had misunderstood) were expanded.

6.1.4 Planned improvements

Of the planned improvements listed in the last NIR, the following have been implemented in the present submission:

- Complete revision of the land-use matrix, and validation of the data points, for the year 1990, on the basis of additional, large-scale maps derived from CIR data records (Chap. 6.3).
- Implementation of new, country-specific CO_2, N_2O and CH_4 emission factors for organic soils.
- Introduction of the provisional final version of a newly prepared "organic soils map" (scale of 1:25,000) within the reporting system.

- Determination of a new emission factor for hedges and field copses, using the complete data records of the research project "Development of methods for determining the biomass of plants, outside of forests, with multiple years of wood growth" ("Methodenentwicklung zur Erfassung der Biomasse mehrjährig verholzter Pflanzen außerhalb von Wäldern").
- Introduction of new, country-specific, on-site emission factors for peat extraction; expansion of reporting to include methane and nitrous oxide emissions.
- Use of the first regional results (Lower Saxony) from the Agricultural Soil Inventory (Bodenzustandserhebung Landwirtschaft) for validation purposes (CRF categories 4.B – 4.C)

In addition to the already announced improvement measures:

- Improvement of the emission factor for the biomass of perennial crops, by including the biomass of short-rotation plantations and tree nurseries and fine-tuning the model.

The following inventory-improvement measures are also planned:

- Development of new, country-specific emission factors for mineral soils, via a major inventory (Agricultural Soil Inventory); the process is to be completed by the NIR 2020 at the earliest.
- Complete integration of the organic soils map within the sampling procedure used in the grid-point approach for determination of the land-use matrix.
- Derivation of country-specific emission factors, and development of models for determination of the impacts of cultivation on cropland and grassland areas, using data from the Agricultural Soil Inventory, data from long-term soil monitoring and mathematical models (by 2018 at the earliest).

The time frame for implementation of these measures will depend on the times at which the research projects being carried out for these purposes conclude and are able to publish their results. In addition, it will be subject to quality checks for reporting purposes. In keeping with the "provisions for preparation and quality management of emissions and carbon inventories for the area of category 4" (THÜNEN-INSTITUT 2012), new activity data and emission factors will first be quality-checked in keeping with defined criteria and then approved for reporting purposes.

6.2 Land-use definitions and land-use classification systems, and their reflection in the LULUCF categories

With the introduction of the sample-point grid system, the various land-use definitions from the underlying data sources (Basis-DLM of ATKIS® and CORINE Land Cover; cf. Chapter 6.3.1.1 and CIR data) had to be correlated with the LULUCF reporting categories.

The Basis-DLM's new AAA model has been in place for all of Germany since 2013. The above-listed IPCC categories are directly allocated to the object types used in the Basis-DLM (AAA levels) of ATKIS®. The data records for the years 2009 through 2012 are mixed versions (AAA levels and the old model); prior to 2009, only the old model was used (in the following, that model is referred to as "levels") (Table 269).

In preparation of the land-use matrix, grid-point allocation is computerized; it is carried out fully automatically via dedicated programmes. In support of that purpose, the allocation keys for these classification systems are included in digital form, with the result that any given grid point can always be unambiguously allocated to an object-type-key number and, thus, to a specific land-use type and IPCC category, regardless of the data source being used. The scripts for these programmes are maintained in the inventory description.

Table 269: Allocation of main object-type index numbers and attributes in ATKIS® to IPCC land-use categories

ATKIS Object-type catalog					CORINE LAND COVER
Object number, AAA levels	**Attribute, AAA levels**	**Object number, levels**	**Object type**	**Description / attributes pursuant to ATKIS object-type catalog**	**Nomenclature code**
IPCC category: Forest Land					
43002	VEG, all	4107	Forest Land	Deciduous, coniferous and mixed forest	311; 312; 313; 324
IPCC category: Cropland					
43001	VEG 1010	4101	Agriculture: Cropland	Area for cultivation of field crops (such as grain, legumes, root crops) and berries (such as strawberries) Cropland also includes rotational set-asides, permanent set-asides and areas set aside to achieve eligibility for EU compensation payments.	211; 212
43001	VEG 1011		Agriculture: Streuobstacker – silvoarable form of traditional *Streuobst* orchards	A Streuobstacker is a cropland area on which fruit trees are allowed to grow (often, in dispersed, irregular patterns).	211; 212
43001	VEG 1012	4109	Agriculture: Hops	Hops	211; 212
43001	VEG 1021		Agriculture: Streuobstwiese – Meadow orchard, the silvopastoral form of traditional *Streuobst* orchards	A meadow orchard is a grassland area on which fruit trees are allowed to grow (often, in dispersed, irregular patterns).	211; 212
43001	VEG 1030	4103	Agriculture: Horticultural land	Horticultural land is land for cultivation of vegetables, fruit and flowers, and for growing of cultivated plants	211; 212
43001	VEG 1031	4109	Agriculture: Tree nursery	Tree nursery	211; 212
43001	VEG 1040	4109	Agriculture: Vineyard	Vineyard	211; 212
43001	VEG 1050	4109	Agriculture: Fruit plantation	Fruit plantation	211; 212
IPCC category: Grassland					
43001	VEG 1020	4102	Agriculture: Grassland	Grassland is a grassy area that is mowed or grazed.	231; 321
43004		4104	Heath	A heath area is a sandy area (typically) with certain typical shrubs and grasses, and with sparse, scrub tree cover.	322; 421
43006		4106	Marsh Grassland (in a strict sense)	A marsh area is a waterlogged area that is covered with water for part of the year. Areas that are wet for brief periods, after rainfall, are not considered marsh areas.	411
43007	FKT 1300		Wasteland and vegetation-free areas: Semi-natural area	A semi-natural area is an area that is not used for crop cultivation and that is covered with grass, wild herbs and other plants.	No allocation
43003		4108	Woody grassland	Area covered with individual trees, groups of trees, bushes, hedges and shrubs.	243
43007	FKT 1200		Wasteland and vegetation-free areas: Succession area	A succession area is an area that has been permanently set aside from agricultural or other existing use and that is allowed to revert to its original condition – for example, as woody grassland, a bog or a heath.	No allocation

ATKIS Object-type catalog						CORINE LAND COVER
Object number, AAA levels	Attribute, AAA levels	Object number, levels	Object type		Description / attributes pursuant to ATKIS object-type catalog	Nomenclature code
IPCC category: Wetlands						
43005		4105	Bog	Terrestrial wetlands	Uncultivated area whose top layer consists of peaty or decomposed plant remains.	412
41005	AGT 4010	2301	Open-pit mine: Peat extraction			No allocation
43001 to 44007		5101 - 5203, 3402	Waters		For example, dammed reservoirs, rivers at least 12 m wide, canals, storage basins, shifting shorelines and banks. 3402 refers to harbour basins – and, thus, to waters and not settlements (in AAA 44005).	511; 512; 423; 521; 522; 523
IPCC category: Settlements						
41001 to 41010		2101-2352	Settlements		Settlements refer to areas, either with or without buildings and structures, that have been shaped by human occupation or that support human occupation.	111; 112; 121; 131; 132; 133; 142; 141; 142
42001 to 42016		3101-3543	Transport		Transport areas consist of areas, either with or without buildings and structures, that serve and support transports.	122; 123; 124
42007	FKT 1100		Wasteland and vegetation-free areas: Area accompanying a water body		An area accompanying a water body is an area, either with or without buildings and structures, that is allocated to a watercourse.	122; 123; 124
IPCC category: Other land						
42007	FKT 1000	4120	Wasteland and vegetation-free areas: Areas without vegetation		Areas without significant vegetation cover, as a result of special soil characteristics such as unprotruding rocks, sand or ice areas.	331; 332; 333; 334; 335
43008		4199	Area currently undefined		Areas whose characteristics cannot currently be determined, in terms of allocation to object types.	No allocation

6.2.1 Forests

The definition of forest used in the German inventory is in keeping with that given in the 2006 IPCC Guidelines (Chapter 2.2). The manner in which areas defined by national land-use systems are allocated to this category is shown in Table 269.

The basis for reporting consists of the definition of forest used by the National Forest Inventory (Bundeswaldinventur (BWI); BMVEL, 2001):

"Forest" within the meaning of the BWI is any area of ground covered by forest vegetation, irrespective of the information in the relevant cadastral survey or similar records. The term "forest" also refers to cutover or thinned areas, forest tracks, firebreaks, openings and clearings, forest glades, feeding grounds for game, timber yards / lumberyards, forest aisles for conduction, further areas linked to and serving the forest including areas with recreation facilities, overgrown heaths and moorland, overgrown former pastures, alpine pastures and rough pastures, as well as areas of dwarf pines and green alders. Heaths, moorland, pastures, alpine pastures and rough pastures are considered to be overgrown if the natural forest cover has reached an average age of five years and if at least 50 % of the area is covered by forest. Forested areas of less than 1,000 m^2 located in farmland or in developed regions, narrow thickets less than 10 m wide, Christmas tree and decorative brushwood cultivations and parkland belonging to residential areas shall not constitute forest within the meaning of the BWI. Watercourses up to 5 m wide do not break the continuity of a forest area.

At the same time, in a departure from the BWI definition of "forest", areas that the BWI counts as forest, but places in the forest category "non-forest ground", i.e. because they are not wooded, were not taken into account in calculation of carbon stocks and carbon-stock changes. While short-rotation plantations are recorded separately in the BWI, they are not forest within the meaning of the Forest Inventory, the Federal Forest Act and the present inventory. They are reported under Cropland.

Pursuant to the 2006 IPCC Guidelines, Land converted to Forest Land remains in the conversion category for at least 20 years and is subsequently included in Forest Land remaining Forest Land. For afforestation areas, data for the period as of 1970 are taken into account.

6.2.2 Cropland

The definition of Cropland used in the German inventory is in keeping with that given in the 2006 IPCC Guidelines (Vol. 4, Chapter 3.2). The manner in which areas defined by national land-use systems are allocated to this category is shown in Table 252.

For purposes of emissions calculations, such land-use systems are stratified by specific pools:

- Calculation of biomass stocks: Annually variable stratification relative to 65 annual crops (Chapter 6.5.2.1.2) and permanent crops. Permanent crops are divided into the categories wine grapes (Chapter 19.4.3.1.3), various fruit-tree categories (Chapter 19.4.3.1.1), Christmas trees (Chapter 19.4.3.1.2), tree nurseries (Chapter 19.4.3.1.5) and short-rotation plantations (Chapter 19.4.3.1.4). Permanent crops accounted for a 1.3 % share of the total cropland area in 2013.
- Calculation of the emissions from soils: Chronologically constant stratification in accordance with the categories of organic soils and mineral soils. The mineral soils category is subdivided by usage, soil type / soil-parent-rock groups and climate region (cf. Chapter 19.4.2.2).
- The total area of open drainage ditches is determined along with the area of organic soils under cropland.
- Calculation of the emissions from land-use changes: Annually updated stratification in accordance with the categories "Cropland remaining Cropland" and "Land converted to Cropland". The relevant data are taken annually from the pertinent land-use information (Chapter 6.3; Chapter 6.4).

6.2.3 Grassland

Grassland as defined in the German inventory is in keeping with the definition given in the 2006 IPCC Guidelines (Vol. 4, Chapter 3.2). The manner in which areas defined by national land-use systems are allocated to this category is shown in Table 252.

Grassland is divided into two sub-categories: a) areas covered with grasses and herbs (Grünland im engeren Sinn / Grassland in a strict Sense) and b) areas that are covered with trees and shrubs (Gehölze / Woody Grassland) but do not fall within the definition of "forest". It also includes object type 4106 "swamp, reeds" from the Basic Digital Landscape Model (Digitales Basis-Landschaftsmodell; Basis-DLM) (Chapter 6.3.2.1), which consists of undrained organic soils under grassland. In the following, such areas are also referred to as "wet grassland". In 2013, Grassland (in the strict sense) accounted for 90.6 % of the total grassland area, while woody grassland accounted for 9.4 % of that total area.

The sub-categories in this area include the following types of land use and plants:

- Meadows, pastures, alpine pastures, rough pastures, heath areas, natural-condition grassland, recreational areas and swamp/reeds are grouped under "grassland (in a strict sense)".
- Hedges, field copses and shrubbery make up the sub-category "woody grassland".

Changes between these two sub-categories are treated like land-use changes.

For purposes of emissions calculation, the two grassland sub-categories have been stratified by pools. To that end, area-weighted mean carbon stocks are determined, and the resulting figures are used in the inventory:

- Calculation of biomass stocks: Stratification within the sub-categories, by crop types. For grassland (in a strict sense), the stratifications include above-ground and below-ground biomass of grasses and herbaceous plants (Chapter 6.6.2.2.1). For woody grassland, a carbon-equilibrium value has been determined for hedge plants and field copses, stratified by species combinations, age, growth density and growth height (Chapter 6.6.2.2.2).
- Calculation of the emissions from soils: Chronologically constant stratification in accordance with the categories of organic soils and mineral soils.
    - The organic soils are subdivided into wet areas (depth to water table < 0.1 m) and drained areas (depth to water table > 0.1 m) (cf. Chapter 6.1.2.2). In addition, the total area of drainage ditches has been estimated.
    - The mineral soils category is subdivided by usage, soil type / soil-parent-rock groups and climate region (cf. Chapter 18.4.2.2).
- Calculation of emissions from land-use changes: Annually updated stratification, by the categories "grassland (in a strict sense) remaining as grassland (i.s.s.)", "woody grassland remaining as woody grassland" and "land converted to grassland". The relevant data are taken annually from the pertinent land-use information (Chapter 6.2; Chapter 6.3).

6.2.4 Wetlands

Pursuant to the 2006 IPCC Guidelines, the "Wetlands" land-use category must subsume all those land areas whose soils are intermittently or constantly waterlogged, or covered with water, and that do not fall within the land-use categories 4.A, 4.B, 4.C and 4.E. In the German inventory, these areas are combined in the sub-categories "terrestrial wetlands" (IPCC: Other Wetlands) and "waters" (IPCC: Flooded Land). In addition, all areas that are related to peat extraction and combined within an additional sub-category under the land-use category Wetlands (IPCC: Peat Extraction; cf. the 2006 IPCC Guidelines).

The majority of Germany's former wetlands areas have been drained and are used mainly for agriculture and forestry (1,681 kha ≙ 92 %). Those areas are reported in the relevant land-use categories (4.A - 4.C) pursuant to the 2006 IPCC Guidelines. The sub-category "terrestrial wetlands" thus includes Germany's few remaining undrained, semi-natural (i.e. subject to very little anthropogenic influence) bogs, along with certain other wetlands on mineral soils and peat-extraction areas. Similarly, in the sub-category Waters, a distinction is made in terms of the applicable degree of anthropogenic impact: between "flooded land" (water bodies that are regulated by human action and that exhibit large fluctuations in their water levels and area coverage – for example, dammed reservoirs, etc.; 2006 IPCC Guidelines) and regulated and non-regulated natural water bodies (not subject to reporting obligations). Figure 66 shows how Germany's wetlands areas have been classified, for the year 2013, in accordance with these provisions.

<table>
<tr><th colspan="7">4.D Wetlands
[681.280 ha]</th></tr>
<tr><th colspan="4">Terrestrial Wetlands
[65.715 ha]</th><th>Peat extraction
[19.857 ha]</th><th colspan="2">Flooded Land/Waters
[595.709 ha]</th></tr>
<tr><td colspan="2">Mineral soils
[28.897 ha]</td><td colspan="2">Organic soils
[36.817 ha]</td><td>Organic soils
[19.857 ha]</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td colspan="2">undrained
[28.897 ha]</td><td colspan="2">drained [13.430 ha]
/
undrained [23.387 ha]</td><td>drained
[19.857 ha]</td></tr>
<tr><td>remaining
[27.655 ha]</td><td>converted
[1.243 ha]</td><td>remaining
[36.597 ha]</td><td>converted
[220 ha]</td><td>remaining
[19.857 ha]</td><td>remaining
[594.310 ha]</td><td>converted
[1.398 ha]</td></tr>
<tr><td colspan="2">Natural and semi-natural wetlands (e.g. marsh areas, marsh districts, banks watersides, riversides)</td><td>Natural and semi-natural wetlands (e.g. fens, bogs)</td><td>Rewetted peatlands</td><td>Peat extraction</td><td></td><td></td></tr>
<tr><td>no emissions</td><td>Emissions: Mineral soils, Biomass</td><td>Emissions: Organic soils, Biomass</td><td>Emissions: Organic soils, Biomass</td><td>Emissions: on-site, off-site</td><td>no emissions</td><td>Emissions: Biomass</td></tr>
</table>

Figure 53: Assignment, for the year 2013, of Germany's water-body and terrestrial wetlands areas [ha] to the "Wetlands" land-use category pursuant to the 2006 IPCC Guidelines

The sub-categories "peat extraction", "terrestrial wetlands" and "waters" differ in terms of their emissions behaviour. For this reason, they are listed as separate sub-categories and reported separately in the CRF tables (for details, cf. Chapter 6.3. In the Wetlands land-use category, land areas are calculated with the help of annually updated stratification by terrestrial wetlands and waters remaining as such, as well as by land converted into waters or terrestrial wetlands. The relevant data are taken annually from the pertinent land-use information (Chapter 6.3; Chapter 6.4). With regard to the peat-extraction area, a constant value of 19,857 ha is assumed (cf. Chapter 6.7.2.4.1); that area does not participate in transfers and thus is reported only in the final-use category. Conversions of waters into terrestrial wetlands and vice versa are treated like land-use changes from other land-use categories.

For purposes of emissions calculation, the wetlands sub-categories, peat extraction, terrestrial wetlands and waters, are stratified by pools. To that end, area-weighted mean carbon stocks are determined, and the resulting figures are used in the inventory:

Non-transfer ("remaining") category:

- Calculation of biomass stocks: No biomass is reported in the sub-category "waters". The biomass of the sub-category "terrestrial wetlands" has been derived from the relevant figures for grassland (in a strict sense) and woody grassland (Chapter 6.8.2.2).
- Calculation of the emissions from mineral soils: No emissions in all sub-categories. In the tables, the emissions are listed as NO.
- Calculation of the emissions from organic soils: For peat-extraction areas, both on-site and off-site emissions are calculated (Chapter 6.7.2.4.1), in keeping with the 2006 IPCC Guidelines and the 2013 IPCC Supplement Wetlands. The terrestrial wetlands sub-category is divided into wet (depth to water table < 0.1 m) and drained areas (depth to water table > 0.1 m) (cf. Chapter 6.1.2.2); on-site emissions are reported, but no emissions are reported for the sub-category waters (Chapter 6.8.2.4).

Transfer categories:

- Calculation of biomass stocks: No biomass is reported in the sub-category "waters". The biomass of the sub-category "terrestrial wetlands" has been derived from the relevant figures for grassland (in a strict sense) and woody grassland (Chapter 6.8.2.2, cf. Chapter 6.6.2.2.2).
- Calculation of the emissions from soils: No emissions are listed for the sub-category "waters". The "terrestrial wetlands" sub-category is differentiated, in a constant manner over time, by "organic soils" and "mineral soils". For organic soils, on-site emissions are reported, following subdivision of such soils into wet (depth to water table < 0.1 m) and drained areas (depth to water table > 0.1 m) (Chapter 6.8.2.4). The mineral soils category is subdivided by usage, soil type / soil-parent-rock groups and climate region (cf. Chapter 19.4.2.2).

6.2.5 Settlements

The categories used by national land-use systems in connection with the categories Settlements and Transport, and the manner in which those categories are allocated to the IPCC's Settlements land-use category, are shown in Table 252. The definition of Settlements used in the German inventory is in keeping with that given in the 2006 IPCC Guidelines (Chapter 2.2). All settlement lands have been combined within a single category.

For purposes of emissions calculations, the settlement category is stratified by specific pools. To that end, area-weighted mean carbon stocks are determined, and the resulting figures are used in the inventory:

- Calculation of biomass stocks: The biomass of the Settlements category has been derived from the relevant figures for grassland (in a strict sense) and woody grassland (Chapter 6.8.2.2, cf. Chapter 6.6.2.2.2).
- Calculation of the emissions from soils: Differentiation, unchanging over time, by organic and mineral soils. Mineral soils are subdivided by soil type / soil-parent-rock groups and climate region (cf. Chapter 19.4.2.2). For organic soils, the values for Grassland (in the strict sense) are used, on a proxy basis (Chapter 6.1.2.2).

- Calculation of the emissions from land-use changes: Annually updated stratification in accordance with the categories "settlements remaining settlements" and "land converted to settlements". The relevant data are taken annually from the pertinent land-use information (Chapter 6.3; Chapter 6.4).

6.2.6 Other land

The following object types defined in ATKIS® are assigned to the "Other land" category within the German reporting system, in keeping with the 2006 IPCC Guidelines: "area currently not classifiable" (object number 4199), and "vegetation-free areas" (object number 4120). The relevant areas are described and allocated in keeping with Table 269 in Chapter 6.2 and the algorithms described in that section.

6.3 Information on approaches used for determining relevant land areas and on the sources of land-use data used

6.3.1 Introduction

The method for determining land-use changes in the LULUCF sector takes account of all land-use categories and land-use changes in a chronologically and spatially consistent manner. The method employs a sample-based system. It is based on the grid for the National Forest Inventory (BWI) 2012. The method expands the existing sample-based system for determining forest-land areas, and land-use changes to and from forest land, for all land-use categories and change types.

6.3.1.1 Database and data processing

The flexible LULUCF survey system consists of all available geographically explicit data sets. At the same time, a data set does not have to cover all of the land-use classes; it simply has to include at least one of the six main land-use classes. In each case, not every data set has to show all land-use classes; only one – at least – of the six main land-use classes has to be shown. Each sample point has a set of associated data distributed over time. Such data sets differ with regard to their numbers of data items, to their quality with respect to errors of position, preparation and interpretation and, in some cases, with regard to their underlying definitions.

The aims with this flexible LULUCF data-collection system thus do not include recording land-use changes as often as possible. Instead, they comprise the following:

- from the wealth of available information, to identify the most reliable land-use information,
- to filter out and detect land-use changes,
- to eliminate any possible uncertainties and sources of error.

An unambiguous hierarchy system has thus been introduced with those aims in mind. Within that system, data records have been arranged into a hierarchy of groups beginning with the most precise data (1st quality level) and leading to the least precise data (nth quality level), with precision in each case determined as of the relevant time of data collection. Within the hiearchical system, each entry refers to the state of land use in the year in which the relevant data source was collected, rather than to the pertinent change over one year or one period. If, for a given year and one given sample point, several different land-use data items are available, from different data sources, then the data record with the highest quality level (QL), pursuant to the hierarchy system, is used to define the pertinent land-use class. Where data sources with the same quality level show different land-use categories, additional rules for applicable decision-making have been defined and documented. Such rules can be oriented to references such as verification data – for example, trends shown in agricultural statistics – that are not available in georeferenced form.

6.3.1.2 Data sources

The following data sources / records have been used:

- Information relative to the forest-oriented LULUCF classes from the National Forest Inventory (Bundeswaldinventur) 1987 and 2002, for the period 1987 to 2002 for the old German Länder; data of the National Forest Inventory 2002 and the Inventory Study (Inventurstudie) 2008 (OEHMICHEN et al. 2011), for 2002 to 2008 for all Germany, and data of the Inventory Study 2008 and the National Forest Inventory 2012 for the period 2008 through 2012,
- Maps, derived from CIR data, from the mapping of biotopes and use types carried out for 1992
- The Basic Digital Landscape Model (Digitales Basis-Landschaftsmodell; Basis-DLM) for the years 2000, 2005, 2008, 2012 and 2013,
- CORINE 1990, 2000, 2006,
- GSE data for 1990, and for 2002 to 2006, for the new German Länder.

1st quality level: BWI data

a) BWI data:

Details relative to the National Forest Inventory (BWI) are described in Chapter 6.5.2.1.1. The BWI is a permanent, systematic cluster sample that is collected periodically. At present, BWI data are available referenced to 1987, 2002 and 2012 and, in a sub-sample, to 2008 (Inventory Study 2008). The data of the BWI 2012 provide precise information, as of the first commitment period for the year 2012 and as of the beginning of the second commitment period for the year 2013, relative to land use (forest land remaining forest land) and land-use changes to forest land (afforestation) or from forest land (deforestation). Land uses, and land-use changes to forest land (afforestation) or from forest land (deforestation), are determined for each sample point, with the help of aerial photographs, country-specific map sets and in situ inspections. The basis for relevant reporting, pursuant to the UN Framework Convention on Climate Change, consists of the definition of "forest" used by the National Forest Inventory (BMVEL, 2001); cf. Chapter 6.2.

The first German report under the Kyoto Protocol uses the following definition of "forest", which accords with the relevant FAO definition:

- Land with tree crown cover of more than 10% of the area;
- The minimum land area to be taken into consideration is 0.1 ha;
- The potential tree height is at least 5 meters.

Within the limits defined by the Marrakesh Accords, that definition is the one that comes closest to the definition used in the National Forest Inventory. Studies (TOMTER et al. 2010) comparing activity-data calculations using the aforementioned definitions have found that the resulting discrepancies are negligible. For that reason, the same area-estimation algorithms have been used for purposes of both the UN Framework Convention on Climate Change and the Kyoto Protocol. At the same time, in a departure from the BWI definition of "forest", areas that the BWI counts as forest, but places in the forest category non-woodland, i.e. because they are not permanently non-wooded, were not taken into account in the forestry sector in calculation of carbon stocks and carbon-stock changes.

For the new German Länder, no forest / non-forest information was available for the year 1987 at the relevant BWI points. In the interest of obtaining a maximally consistent database for the new German Länder, the individual-tree data of the BWI 2002 were used in the following manner: for 1987, the sample points were retroactively assigned to the land-use class Forest Land for those cases in which the BWI 2002, at the pertinent forest cluster points, listed trees that were more than 15 years old.

b) CIR data:

The CIR data are thematic maps prepared from color-infrared aerial photos. The aerial photos have a resolution of about 40 cm and thus provide a considerably improved data framework for the Corine data. The thematic-map data, in terms of time precision (the data include precise records of when the photographs were taken) and degree of detail, are superior even to those of the Basic Digital Landscape Model (Digitales Basis-Landschaftsmodell; Basis-DLM). The action plan for solving the problems determined in the In-country Review 2010, in connection with KP LULUCF, is being implemented via use of the CIR data for validation and improvement of the 1990 land-use data. In the years 1989 through 1992, the German Länder (states) Schleswig-Holstein, Saxony, Saxony-Anhalt, Brandenburg, Mecklenburg – West Pomerania and Thuringia used legally mandated biotope-mapping programmes as an opportunity to map their entire territories. As of this report year, all CIR data are being used. Each such data set has been used with the help of an individualised table for conversion into the Basis-DLM format.

2nd quality level: Basis-DLM data

The Basic Digital Landscape Model (Basis–Digitale Landschaftsmodell; Basis-DLM) is the basis for Germany's Official Topographical-Cartographical Infomation System (Amtliches Topographisch-Kartographischen Informationssystem; ATKIS®), which is managed by the Working Committee of the Surveying Authorities of the States of the Federal Republic of Germany (AdV). The ATKIS® system describes Germany's topography in terms of digital landscape and terrain models. "The Basis-DLM uses a vector format to describe topographic objects of the landscapes and the relief of the earth's surface. Each object is assigned to a specific object type and defined in terms of its spatial position, geometric type, descriptive attributes and relations to other objects. Each object has an identification number (identifier) that is unique throughout all objects for Germany. In the Basis-DLM, spatial position is given true to scale, and independently of any representations, within the coordinate system used for land surveying. The object types contained in the DLM, and the manner in which the objects are to be formed, are defined in the ATKIS® object-type catalogue (ATKIS®-OK)" (AdV). The informational spectrum of the Basis-DLM is oriented to the contents of standard 1:25,000 topographic maps. At the same time, the Basis-DLM features greater precision of position (± 3m) for the most important point-shaped and line-shaped objects. Data of the Basis-DLM systems of the Länder are adopted by the Federal Agency for Cartography and Geodesy (BKG) and then checked, harmonised, georeferenced and processed, without any overlapping, for use within a nationally standardised Basis-DLM. The BKG also manages the data, within a special database, for purposes of provision to federal authorities and other agencies.

The purpose of ATKIS® is to provide a landscape model (land cover) of Germany, with regularly updated and expanded geometries and content, that is maximally up-to-date and has the highest resolution possible. The surveying administrations of the Länder collect the pertinent data on an ongoing basis; they do not collect data as of a given key date, nor do they collect on a national basis. As a result, new surveying results are continuously transmitted to the Federal Agency for Cartography and Geodesy (BKG) and integrated within ATKIS®. While five years is given as time period within which a complete revision should be accomplished, that specification is applied very differently from state to state (states = German Länder). In practice, the data for areas with vegetation cover are between one and seven years old. For areas of special interest, especially with regard to area changes – such as settlement and transport areas – a period of three to twelve months is prescribed for transfer into ATKIS®. The Basis-DLM version maintained and managed by the BKG is always the latest version. No pertinent history data are recorded, nor are old versions archived.

For the relevant Thünen institutes, this means:

- Basis-DLMs are obtained on an annual basis; the Basis-DLM for a given report year is obtained in September of that year;
- In each case, the version for the current year is archived.

Basis-DLM data sets have been available on an annual basis to the Thünen institutes only since 2005. One data set is available for the year 2000. No ATKIS® data exist for years prior to 2000. Due to the multi-year revision cycles involved, multi-year intervals in the Basis-DLM data records are used, however, to prevent the regional artifacts that can occur via seemingly sudden massing of land-use changes in updating years.

For the period as of 2009, the Basis-DLM is being converted to a new data model, referred to in the following as "AAA levels", to distinguish it from the "levels" referred to under the old model. In the years 2009 through 2012, some German Länder (states) provided data in the old model and some provided data in the new model. As of 2013, the Basis-DLM (AAA levels) is being used for all of Germany.

Each data set in the Basis-DLM (levels) comprises some 800 individual layers of differing degrees of detail. For example, polygons with relatively low resolution (such as those showing settlement areas) are found on the lowest level, while polygons with very high resolution and rich detail (such as those showing residential areas) are found on the highest level. A single record thus will contain numerous superimposed polygons that, in terms of content, can be assigned to the same LULUCF categories. All such related content, with all overlays, is read into the system as a whole. As a result, data gaps occur only where the entire pertinent Basis-DLM data record contains no data. In a subsequent step, the areas so defined are merged with the points of the BWI network. Where a point touches several stacked areas, only a single value is chosen, with the help of a priority list. Where the same priorities overlap (for example, vegetation with vegetation), then that area with the lower ATKIS® identification value is used. The procedure has been carried out for the Basis-DLM (levels) from the years 2000, 2005, 2008 and 2012. The Basis-DLM categories are assigned to the LULUCF classes with the help of a key table (cf. also Table 269).

The new data model (Basis-DLM AAA levels) includes a layer designated "actual use" ("Tatsächliche Nutzung"). "All object types of this object-type area participate in seamless, non-overlapping and complete-coverage description of the earth's surface (land areas)." As a result, problems due to overlapping and gaps are now a thing of the past. Additional attributes emerge in additional layers. The Basis-DLM categories (AAA levels) are assigned to the LULUCF classes with the help of a key table (cf. also Table 252).

3rd quality level: CORINE Land Cover (CLC) data

CORINE Land Cover (CLC) is a European remote-sensing project, initiated by the EU Commission, for standardising classification of land use and land-use changes. In the CLC framework, digital satellite images of European countries are collected, via standardised procedures, and analysed with regard to land-use changes. Image data collected in three different years, 1990, 2000 and 2006, are currently available. CORINE data for the years 1990, 2000 and 2006 have been read into the database with the help of a script. The CORINE classes are allocated to LULUCF classes with the help of a translation table (cf. also Table 269).

4th quality level: GSE data

The GSE Forest Monitoring project is part of the Global Monitoring for Environment and Security (GMES) programme, which was established in 1998 by the European Commission and the European Space Agency (ESA). In the framework of the GSE Forest Monitoring project, the service "Forest Monitoring: Inputs for national greenhouse-gas reporting (GSE FM-INT; "Wald Monitoring: Inputs für die Nationale Treibhausgasberichterstattung") has been introduced for the Federal Ministry of Food and Agriculture (BMEL). The products of that service have included maps of forest cover, land use and land-use changes, for 1990 and for pertinent changes through 2002 and 2005/06; area statistics; and error analyses for the new German Länder (GSE 2003, GSE 2006, GSE 2007, GSE 2009). Further information about the GSE FM-INT project is provided in OEHMICHEN et al. (2011b). For 1989 and 1990, Landsat satellite data were used. For 2001 to 2005, LISS data from the Indian IRS satellites were also used. Forest areas and their changes were classified with the help of Basis-DLM data, aerial photographs, topographic maps and elevation models. Following radiometric and geometric processing of the satellite data, the relevant structures were allocated to LULUCF classes via a monitored classification process. Subsequently, any obvious errors were corrected with the help of additional data sources, such as topographic maps, and any smaller artifacts were removed with filters or by manual retouching. Quality control was carried out on a random-sample basis, using orthophotos. According to the project specifications, all land areas and land-use changes entered into the system have to cover a minimum area of 0.5 hectares. The original data available to the Johann Heinrich von Thünen Institutes include land areas and land-use changes smaller than 0.5ha, and down to a pixel size of 25m x 25m. Such smaller units may be considered similar to the "minimum mapping units" used in the National Forest Inventory (BWI). For purposes of the method used in the present context, the LULUCF categories were divided into land-use classes for the years 1990 and 2005. **The GSE data diffentiate solely according to the categories "Forest Land" and "non- Forest Land"**.

6.3.1.3 Derivation of LULUCF information

Each sample point is assigned the pertinent available information relative to land use for each year and data source. Then, classification in keeping with the LULUCF categories can begin.

This is achieved via retrospective and prospective comparison – with reference to the year under consideration – to determine the time for each point at which land-use information on the highest available quality level is available (QL-MAX retrospective and QL-MAX prospective). This means, for example, that for a BWI point designated as forest to which a land-use class is to be assigned for 2001, data on the 1st quality level are available – the BWI information. Retrospectively, the last survey year for those data is 1987; prospectively, the next survey year is 2002. The LULUCF category is then derived from those two land-use classes, at the years 1987 and 2002. For the year 2012, the data records of the BWI 2012 and the Basis-DLM 2012 apply.

Sample points at which BWI information on land use (forest land remaining forest land), and on classes of land-use change to forest land (afforestation) or from forest land (deforestation), are available were validated via on-site inspections during the forest inventories and may be considered correct. A similar status may be assumed for the CIR data (which contain information about all land uses), since those maps were prepared to a very large scale and were validated via field surveys. The Basis-DLM data for 2012 and 2013 are also considered current and quality-assured, since that project used a strictly hierarchical nomenclature (and was the first to do so). All other records have been reviewed for plausibility of the assigned land-use class, for a given year, on the basis of additional data, and in keeping with the following criteria:

- Can the classification into a specific LULUCF category be substantiated with pertinent data from a lower quality level?
- Is the time series for the land-use categories for the sample point consistent, i.e. is the land use free of multiple changes? In cases with inconsistencies, the land-use change was placed in the relevant valid category for 2012.
- Following placement in a LULUCF category, cases involving land-use changes were reviewed to determine whether data of lower quality levels could be used to narrow down the time period in which the change must have occurred.
- To provide an additional criterion, the national trend in land-use changes (except for those changes to and from forest land) was compared with the national net land-use-change rates obtained via the periodic land inventories and agricultural-structural inventories of the Federal Statistical Office. Those inventories use land-use-category definitions that differ – widely, in some cases – from those used in the present system.

In the following, an example is provided to illustrate the manner in which the time period in which a land-use change occurs is narrowed down. Let us assume that, on the basis of BWI data, a sample point was classified as forest land in 1987 and as settlements in 2002. If no additional data are available, the land-use change is linearly interpolated between those two years, meaning that 1/15 of the represented area would be converted each year from forest land to settlements. If Basis-DLM data are available for the point, and those data also show the category "forest land" for 2000 and also show the category "settlements" for 2005, then placement in the LULUCF class "forest land converted to settlements" would be logical and justified, and the change period could be narrowed down to 2 years (2000 = forest land in the Basis-DLM and 2002 = settlements pursuant to BWI) (cf. also Figure 54).

For each sample point and time, the process of selecting a land-use category – i.e. of carrying out relevant review and decision-making – has been carried out transparently, on the basis of a decision tree (cf. Chap. 6.3.2.1).

In keeping with the provisions of the 2006 IPCC Guidelines, land-use changes as of 1970 are already being taken into account in reporting under the UN Framework Convention on Climate Change. As a result, the transition categories are already being filled with areas in a manner that enables them, as of 1990, to reach a stable dynamic state comprising additions of new change areas and transfers of areas into relevant final-use categories. At present, the earliest georeferenced data available for Germany date from the BWI 1987; and, in general, for the period prior to 1990, no complete and internally consistent (the latter aspect is even more important) national data sets are available. Consequently, the changes in all land-use categories in the period 1990 - 2000 were extrapolated retroactively to 1970. That approach is in keeping with that used, for example, by the Czech Republic and by Austria for the land-use matrix.

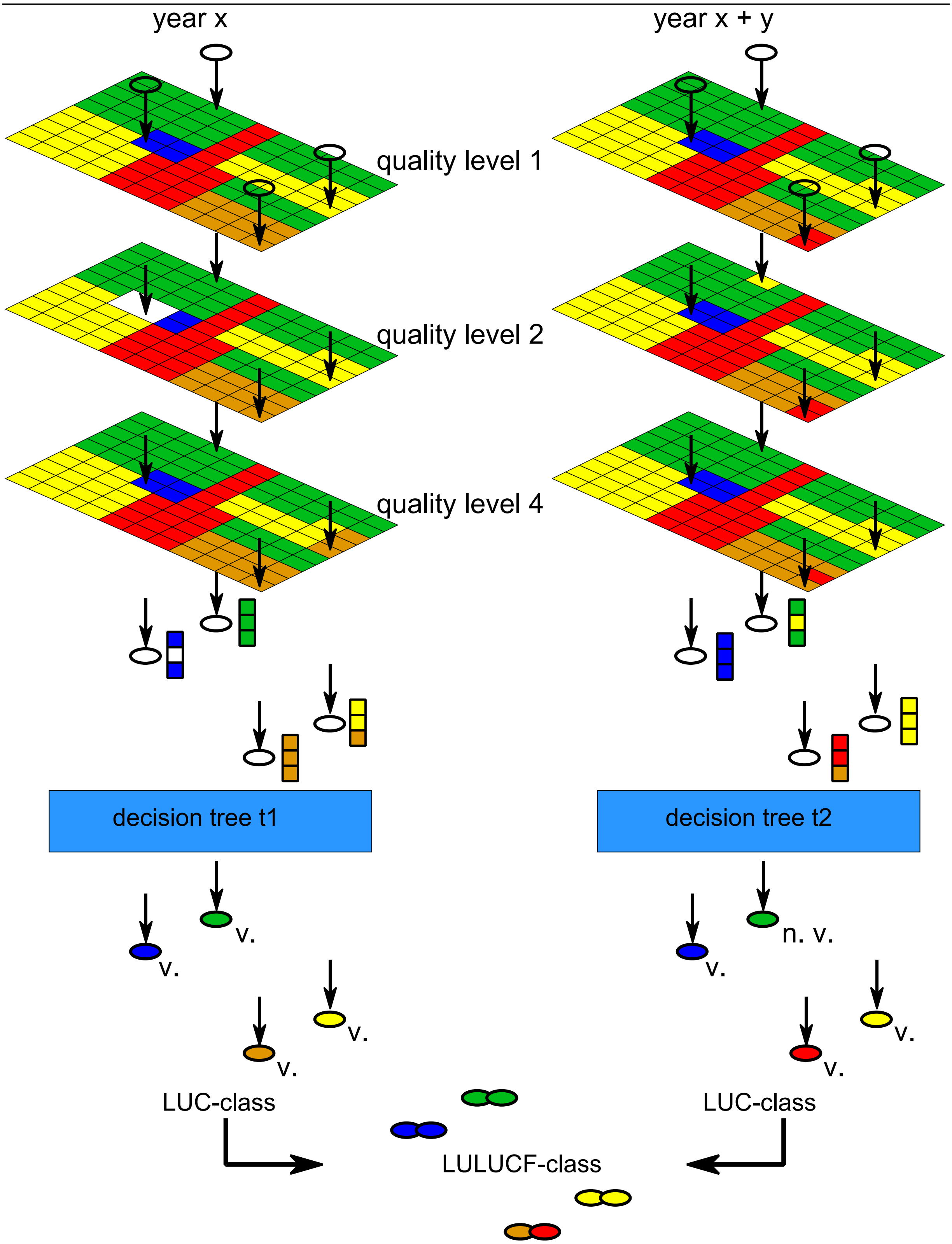

Figure 54: Schematic representation of allocation of sample points to a land-use category

6.3.1.4 Validation and error assessment

With the sampling method, various sources of error, such as

- additional sampling errors,
- differences in definitions, and
- discrepancies between Minimum Mapping Units,

can be quantified. On the other hand, error determination is hampered by the impossibility of achieving 100% accuracy in georeferencing of data sets.

Still, the three error sources mentioned immediately above can be eliminated, over time, via this flexible, sample-based system. The reason for this is as follows: Pursuant to the decision tree, placement within a LULUCF category is assumed correct only if such placement has been derived from suitably precise data sets on the 1st quality level, and data from a lower quality level confirm the placement. In every other case – i.e. whenever different data sources disagree about land use at a given time – the relevant sample point has had to be evaluated with the help of aerial photos (whenever such photos have been available). Such evaluation was carried out for several German Länder (states) for the year 1990, for example. In the small numbers of cases, regarding the nature of specific points, in which even aerial photos did not make a decision possible, or in which no aerial photos are available, the points were inspected on-site, if possible. Time-series inconsistencies resulting from use of data sets with differing definitions, or different Minimum Mapping Units, and inconsistencies tied to imprecise geographic locations, can no longer occur as a result of such additional validation.

6.3.2 Step-by-step implementation

Complete implementation of this described new system for detecting land-use changes throughout Germany, over time, will necessitate extensive preliminary work and continuous supporting efforts. For example, the following have to be carried out:

- The various data materials, for different points in time, have to be acquired,
- Geometric corrections (of erroneous geometries, etc.) and checks have to be carried out,
- Conversion functions have to be written for converting the original classifications into LULUCF categories,
- The sample points have to be merged with the maps,
- The decision tree has to be programmed and adjusted as necessary, in keeping with data quality and availability, and
- The "transition-time" procedures have to be programmed and adjusted as necessary, in keeping with data quality and availability.

The decision to use this flexible, sample-based system was made in spring 2011, in consultation with the Single National Entity (Federal Environment Agency – UBA) and the Federal Ministry of Food and Agriculture (BMEL), which is responsible for the forest inventories.

Programming of the decision trees for each classification year, and of the "transition-time" procedures, has been adapted in keeping with this current data structure.

6.3.2.1 Derivation of land uses

Each sample point can be assigned to a land-use category for the years in question (1990, 2000, 2005, 2008, 2012 and 2013), on the basis of the available data (cf. Chapter 6.3.1.1), and in keeping with the relevant quality levels. The basic table 246 is structured as follows:

Table 270: Basis for derivation of land uses

Cluster	Cluster point	BWI 1987	BWI 2002	BWI 2008	DLM 2000	DLM 2005	DLM 2008	DLM 2012	DLM 2013	CORINE 1990	CORINE 2000	CORINE 2006	GSE 1990	GSE 2005
xya	1	forl	sett	sett	forl	sett	sett	sett	sett	forl	gra1	sett	gse0	gse0

The following codes are used for the land-use classes in the data records:

Table 271: Codes in the basic table

Code	Category	Sub-category
crop	Cropland	Cropland
gra1	Grassland	Grassland (in a strict sense)
gra2	Grassland	Woody grassland
forl	Forest Land	Forest Land
wet1	Wetlands	Terrestrial wetlands
wet2	Wetlands	Waters
sett	Settlements	Settlements
othl	Other land	Other land
nofo	Non-forest land	The information is from BWI data, needs to be further specified with the help of other data sources and must be non-forest land.
bwi0	No information	No land-use information at this point in BWI data
dlm0	No information	No land-use information at this point in Basis-DLM data
clc0	No information	No land-use information at this point in CORINE data
gse0	No information	No land-use information at this point in GSE data

For the years 1990, 2000, 2005, 2008, 2012 and 2013, the decision trees were applied to the relevant year. Figure 55 shows, by way of example, the decision tree for 2012. In reading the decision trees, it must be noted that all lines consist of "IF - ELSE IF - ELSE" structures, rather than simple "IF - THEN - ELSE" structures. In other words, when a condition applies, it is implemented. All subsequent conditions are then irrelevant. This structure considerably simplifies the query logic.

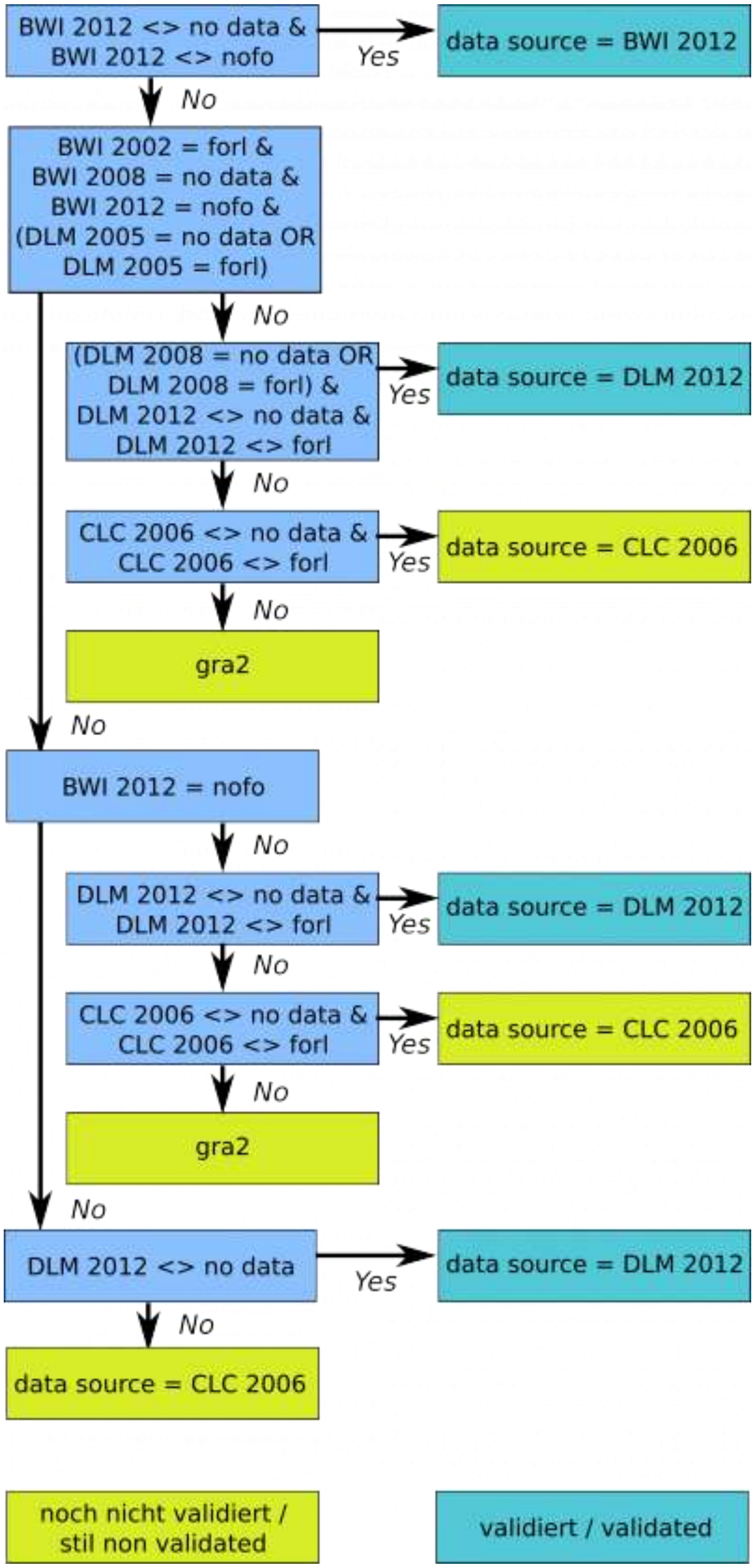

Figure 55: Decision tree for the year 2012, presented by way of illustration (for abbreviations, cf. Table 271)

Use of the decision trees yields a further table (cf. Table 272), with the most probable land uses per sample point and year (1990, 2000, 2005, 2008, 2012 and 2013) and the best data source in each case. The BWI data are listed only for actual forest land, where the BWI returns the information "non-forest land", other data sources are used from then on to determine the land use:

Table 272: Most probable land use (LU) and pertinent data sources (DB) (For abbreviations, see Table 271)

Cluster	Cluster point	LU 1990	LU 2000	LU 2005	LU 2008	LU 2012	LU 2013	DB 1990	DB 2000	DB 2005	DB 2008	DB 2012	DB 2013
xya	1	forl	forl	sett	sett	sett	sett	bwi	dlm	dlm	dlm	dlm	dlm

6.3.2.2 Derivation of annual land-use changes

Subsequently, the relevant land-use-change classes were derived for each change period (1990-2000, 2000-2005, 2005-2008, 2008-2012 and 2012-2013) and each sample point. To that end, an SQL script was programmed; it is documented in the inventory description.

The applicable transition times were implemented in several partial steps. For all land-use changes that occur within a period covered by the included observations (1990-2013), processing was carried out on a point-oriented basis. At the same time, the land-use changes have been spatially correlated with the individual observation points. Land-use changes that occurred prior to that period (1970-1990) are extrapolated retroactively from observations carried out during the first measurement period (1990-2000). In those cases, spatial correlation with the observation points is no longer required, nor is it even possible. As a result, for those cases a change is made from point-based processing to calculation on the basis of area sums.

No useful annual change data are available within the observation period, as is explained in the methods section. The observation period is divided into change periods of differing lengths (1990-2000, 2000-2005, 2005-2008, 2008-2012), and the annual changes in those change periods are calculated on a proportional basis, via linear interpolation.

6.3.3 Land-use changes pursuant to the Convention and the KP

The method described here for determining land-use changes, and the resulting land-use matrix (cf. Table 273), including a 20-year transition time beginning in 1970, are compliant with reporting requirements pursuant to the UN Framework Convention on Climate Change, as set forth in the 2006 IPCC Guidelines. Table 274 shows the complete detailed land-use matrix for 2013 by way of example.

For determination of land-use changes pursuant to the Kyoto Protocol, the same set of annual data is used (cf. Table 275), but only land-use changes since 1990 are taken into account and, in the change categories of afforestation and deforestation, they are accumulated for more than 20 years (cf. Table 349 in Chapter 11.2.2).

Table 273: Land-use changes (LUC), including 20-year transition time, pursuant to reporting under the Convention

Category	4.A.1 Forest land remaining forest land	4.A.2 … LUC to forest land	4.B.1 Cropland remaining cropland	4.A.2 … LUC to cropland	4.C.1 Grassland remaining grassland	4.A.2 … LUC to grassland	4.D.1 Wetlands remaining wetlands	4.A.2 … LUC to wetlands	4.E.1 Settlements remaining settlements	4.A.2 … LUC to settlements	4.F.1 Other land remaining other land	4.F.2 … LUC to other land
Units	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha
1990	10,594,097	560,529	12,584,315	1,046,970	6,200,204	967,774	578,106	90,512	2,391,769	683,289	82,069	0
1991	10,609,640	560,529	12,572,729	1,046,970	6,179,095	967,774	576,749	90,512	2,412,697	683,289	79,649	0
1992	10,625,184	560,529	12,561,143	1,046,970	6,157,986	967,774	575,391	90,512	2,433,626	683,289	77,229	0
1993	10,640,727	560,529	12,549,557	1,046,970	6,136,878	967,774	574,034	90,512	2,454,554	683,289	74,809	0
1994	10,656,271	560,529	12,537,972	1,046,970	6,115,769	967,774	572,677	90,512	2,475,482	683,289	72,389	0
1995	10,671,815	560,529	12,526,386	1,046,970	6,094,660	967,774	571,320	90,512	2,496,410	683,289	69,969	0
1996	10,687,358	560,529	12,514,800	1,046,970	6,073,552	967,774	569,962	90,512	2,517,338	683,289	67,549	0
1997	10,702,902	560,529	12,503,215	1,046,970	6,052,443	967,774	568,605	90,512	2,538,267	683,289	65,129	0
1998	10,718,445	560,529	12,491,629	1,046,970	6,031,334	967,774	567,248	90,512	2,559,195	683,289	62,709	0
1999	10,733,989	560,529	12,480,043	1,046,970	6,010,225	967,774	565,891	90,512	2,580,123	683,289	60,288	0
2000	10,749,532	560,529	12,468,458	1,046,970	5,989,117	967,774	564,533	90,512	2,601,051	683,289	57,868	0
2001	10,768,250	546,624	12,451,277	1,016,492	5,998,482	961,578	565,364	91,638	2,623,345	704,350	52,231	0
2002	10,786,969	532,719	12,434,096	986,015	6,007,847	955,382	566,195	92,765	2,645,640	725,412	46,594	0
2003	10,805,687	518,814	12,416,915	955,537	6,017,212	949,186	567,026	93,891	2,667,934	746,473	40,957	0
2004	10,824,405	504,909	12,399,734	925,059	6,026,578	942,990	567,857	95,017	2,690,228	767,535	35,320	0
2005	10,843,123	491,005	12,382,553	894,582	6,035,943	936,794	568,688	96,143	2,712,522	788,596	29,683	0
2006	10,859,878	477,504	12,383,209	923,229	5,983,113	922,586	571,619	96,610	2,733,931	800,067	27,888	0
2007	10,876,632	464,004	12,383,865	951,876	5,930,283	908,377	574,549	97,076	2,755,339	811,538	26,093	0
2008	10,893,386	450,503	12,384,521	980,523	5,877,454	894,169	577,479	97,543	2,776,748	823,009	24,298	0
2009	10,910,929	439,038	12,384,349	1,009,889	5,821,110	873,814	580,257	95,888	2,802,655	838,430	23,274	0
2010	10,928,471	427,573	12,384,176	1,039,256	5,764,766	853,458	583,036	94,233	2,828,562	853,851	22,250	0
2011	10,946,014	416,108	12,384,004	1,068,622	5,708,422	833,103	585,814	92,579	2,854,469	869,272	21,226	0
2012	10,963,556	404,642	12,383,832	1,097,989	5,652,079	812,748	588,592	90,924	2,880,376	884,693	20,202	0
2013	10,981,066	394,380	12,365,027	1,126,118	5,590,029	793,197	592,020	89,260	2,909,757	918,678	20,102	0

Table 274: Land-use matrix for 2013. In each case, the boldface number on the diagonal shows the area remaining in the same category for the column in question. The other table cells show the relevant land-use changes (including 20-year transition times)

	Land-use matrix for 2013: Areas [ha]										
Initial*Final*	*Forest Land*	*Cropland*	*Grassland (in a strict sense)*	*Woody grassland*	*Terrestrial Wetlands*	*Waters*	*Peat extraction*	*Settlements*	*Other land*	**Σ reductions**	**Σ additions - Σ reductions**
Forest Land	**10,981,066**	36,771	57,980	16,690	3,783	7,345	0	97,620	0	**220,190**	**174,190**
Cropland	129,301	**12,365,027**	477,028	65,278	729	17,662	0	541,502	0	**1,231,500**	**-105,382**
Grassland (in a strict sense)	167,647	1,013,881	**5,077,170**	62,248	14,812	21,272	0	240,454	0	**1,520,314**	**-811,539**
Woody grassland	26,315	13,099	32,886	**417,725**	770	1,758	0	14,615	0	**89,442**	**90,113**
Terrestrial wetlands	6,953	2,157	2,657	539	**44,503**	501	0	7,547	0	**20,355**	**857**
Waters	10,545	5,151	27,944	2,019	278	**526,881**	0	7,013	0	**52,951**	**15,877**
Peat extraction	0	0	0	0	0	0	**19,857**	0	0	**0**	**0**
Settlements	41,480	49,826	93,576	29,357	839	13,008	0	**2,909,757**	0	**228,086**	**690,592**
Other land	12,139	5,234	16,703	3,424	0	7,282	0	9,925	**20,102**	**74,809**	**-74,809**
Σ additions	**394,380**	**1,126,118**	**708,775**	**179,555**	**21,211**	**68,827**	**0**	**918,678**	**0**		
Σ Land-use category	**11,375,446**	**13,491,146**	**5,785,945**	**597,280**	**65,715**	**595,709**	**19,857**	**3,828,434**	**20,102**		
Total area of Germany				**35,779,633**							

Table 275: Annual areas for land-use changes on which calculations for the UNFCCC inventory (20-year transition period) and KP (cumulative area change) are based [hectares per year]

Land-use change [hectares per year]	**1990-2000**	**2001-2005**	**2006-2008**	**2009-2012**	**2012-2013**
… to forest land					
Cropland to forest land	9,699	4,654	5,656	4,244	4,195
Grassland (in a strict sense) to forest land	11,465	5,794	4,086	8,423	12,468
Woody grassland to forest land	1,847	839	931	1,399	801
Terrestrial wetlands to forest land	579	100	233	425	0
Wetlands to forest land	965	239	266	449	0
Settlements to forest land	2,407	1,997	2,989	1,346	299
Other land to forest land	1,064	498	366	275	0
… to cropland					
Forest land to cropland	3,227	1,558	765	850	700
Grassland (in a strict sense) to cropland	43,132	16,816	77,139	79,770	77,380
Woody grassland to cropland	1,500	200	199	75	701
Terrestrial wetlands to forest land	280	40	0	0	0
Waters to cropland	636	100	33	25	0
Settlements to cropland	3,454	2,318	2,794	995	1,697
Other land to cropland	120	839	67	0	0
… to grassland (in a strict sense)					
Forest land to grassland (in a strict sense)	3,025	3,669	2,592	2,298	1,493
Cropland to grassland (in a strict sense)	31,371	23,550	17,834	16,202	21,371
Woody grassland to grassland (in a strict sense)	3,131	1,534	666	200	500
Terrestrial wetlands to grassland (in a strict sense)	180	200	0	50	200
Waters to grassland (in a strict sense)	2,210	1,439	897	499	599
Settlements to grassland (in a strict sense)	5,210	4,275	4,949	4,798	1,697
Other land to grassland (in a strict sense)	609	1,811	663	350	0
… to woody grassland					
Forest land to woody grassland	877	378	1,698	721	688
Cropland to woody grassland	3,223	4,032	3,790	2,271	2,099
Grassland (in a strict sense) to woody grassland	1,056	4,808	5,181	2,671	4,588
Terrestrial wetlands to woody grassland	20	40	0	50	0
Waters to woody grassland	189	60	99	0	100
Settlements to woody grassland	1,357	2,422	1,592	596	592
Other land to woody grassland	119	318	66	200	0

Land-use change [hectares per year]	**1990-2000**	**2001-2005**	**2006-2008**	**2009-2012**	**2012-2013**
… to terrestrial wetlands					
Forest land to terrestrial wetlands	70	299	533	50	0
Cropland to terrestrial wetlands	90	0	0	0	100
Grassland (in a strict sense) to terrestrial wetlands	250	1,180	1,101	624	1,363
Woody grassland to terrestrial wetlands	110	0	0	0	0
Waters to terrestrial wetlands	40	0	0	0	0
Settlements to terrestrial wetlands	120	0	0	0	0
Other land to terrestrial wetlands	0	0	0	0	0
… to waters					
Forest land to waters	508	139	564	350	0
Cropland to waters	1,326	878	632	449	300
Grassland (in a strict sense) to waters	1,085	1,398	1,198	649	499
Woody grassland to waters	180	40	67	25	0
Terrestrial wetlands to waters	0	20	134	0	0
Settlements to waters	689	859	432	523	500
Other land to waters	99	858	466	200	100
… to settlements					
Forest land to settlements	4,777	3,264	5,121	6,215	7,636
Cropland to settlements	18,225	36,415	23,781	29,354	43,088
Grassland (in a strict sense) to settlements	8,639	12,457	16,034	13,392	16,028
Woody grassland to settlements	1,290	299	465	375	1,198
Terrestrial wetlands to settlements	179	1,238	0	25	0
Waters to settlements	646	239	67	225	199
Other land to settlements	409	1,312	167	0	0

6.3.4 Verification

The land-use categories were selected so as to be in accordance with the relevant definitions pursuant to the UNFCCC, the Kyoto Protocol and the IPCC. Germany uses a range of different definitions for important land-use categories – in particular, agricultural land (Cropland, Grassland) and Settlements. Such use of different definitions, along with different data sources, leads to inconsistencies in land-area figures. While such inconsistencies, on the order of over 10%, or 2 million hectares, per land-use category, have long been known, they have been retained with a view to achieving consistent time series in all data sources.

The three most important data sources in Germany, for data on agricultural areas, are (cf. Table 1)

1. The main soil use survey (Bodennutzungshaupterhebung) of the Federal Statistical Office: It determines land use by surveying agricultural facilities (2012: exhaustive survey). Cropland excludes a number of permanent crops, while Grassland excludes extensive, non-commercial forms of use, such as nature-conservation and recreational uses. The Federal Statistical Office reports the cropland and grassland area data that result from the main soil use survey (Bodennutzungshaupterhebung) to Eurostat. In the inventory, the net area changes, between the cropland and grassland categories, are used for validation of land-use changes.
2. AKTIS digital landscape model (DLM; AKTIS Digitale Landschaftsmodell): It derives land use from the official land-cover cadastre. Its geometries come from topographical maps with scales ranging from 1:5,000 to 1:25,000, and they are corrected and/confirmed via aerial photos. Its content (object types) is determined solely on the basis of aerial photos. Grassland includes all forms of herbaceous vegetation. Roads are depicted as lines, and thus roadside vegetation is classified as grassland, and not as infrastructure. As a result, up to 0.7 million hectares of roadside vegetation are additionally classified as grassland. The DLM is one of the inventory's central data sources. For reasons of transparency, it is used without any after-the-fact editing or reclassification.
3. The area survey (Flächenerhebung) of the Federal Statistical Office: It derives land use from the official real estate cadastre and from the AKTIS DLM. Grassland excludes recreational areas. Because it does not always differentiate sharply between cropland and grassland, cropland and grassland data are published only as summed data for cropland + grassland. While the area survey makes use of data that are largely consistent with the ATKIS DLM, it converts roads from lines into areas (in a post-editing step). While the area survey represents Germany completely, and consistently over time, it does not show a constant national area for the country. The area survey is consistent with the inventory.

Table 276: Cropland and Grassland, and agricultural areas, by data sources, for the year 2012 [1000s of ha]

Land-use category	Main soil use survey (Bodennutzungshaupterhebung)	Inventory	Area survey (Flächenerhebung)
Cropland	11.834	13.804	Not published
Grassland	4.631	5.677	Not published
Total	16.667	19.481	18.647

6.4 Forest land (4.A)

6.4.1 Category description (4.A)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/-/2	**4.A Forest land**		**CO2**	**-74.537,2**	**(6,11%)**	**-56.832,2**	**(6,08%)**	**-23,8%**
-/-	4.A Forest land		N2O	410,2	(0,03%)	311,4	(0,03%)	-24,1%
-/-	4.A Forest land		CH4	51,9	(0,00%)	46,4	(0,00%)	-10,6%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS/Tier 2	RS/NS	CS
CH_4	Tier 2	RS/NS	D/CS
N_2O	Tier 2	RS/NS	D/CS

The category Forest Land is a key category for CO_2 emissions, in terms of emissions level and of Tier 2 analysis.

Reporting in the category *Forest Land* covers CO_2 emissions / removals from/in mineral and organic soils, above-ground and below-ground biomass, litter, dead wood and forest fires; in addition, it covers nitrous oxide emissions from forest fires, and from drainage of organic soils, and methane emissions from forest fires and from drainage.

In 2013, the total emissions from forests amounted to -56,462 Gg CO_2 equivalents. Table 277 lists the emissions for the Forest Land category, broken down by pools and greenhouse gases.

Table 277: Emissions in the Forest Land category for the year 2013

Category	GG	Forest Land, emissions, 2013 [Gg CO_2-eq.] Emission	2.5 perc.	97.5 perc.
Forest Land$_{total}$		-56,461.8	-37,357.5	-76,762.1
Mineral soils	CO_2	-15,547.8	-15,434.8	-23,457.5
	N_2O_{direct}	**55.9**	76.4	179.5
	$N_2O_{indirect}$	**12.6**	100	250.7
Organic soil	CO_2	3,214.0	2,611.6	3,919.9
	N_2O	254.8	41.7	710.5
	CH_4	45.3	6.9	454.1
Biomass	CO_2	-46,366.6	-22,883.5	-69,856.9
Litter	CO_2	-173.2	44.0	-390.5
Dead wood	CO_2	2,041.4	-89.6	4172.5
Forest fires / wildfires	CO_2	IE	-	-
	N_2O	0.7	0.5	1.0
	CH_4	1.1	0.7	1.5

As the time series for emissions from forests (cf. Figure 56 and Figure 57) show, the sum of all greenhouse-gas binding in forests decreased abruptly in 2002 and then increased in 2008. The reason for the jumps is that relevant surveys in the framework of the National Forest

Inventory (BWI) are carried out periodically. Additional details about this aspect are provided in Chapter 6.4.2.2.1.

In the category Forest Land, the most important factors for CO_2 removals are the pools phytomass (66.35 %), mineral soils (23.77 %) and litter (1.69 %). Sources occur via dead wood, drainage, mineralization and forest fires. Such sources account for only a very small share – 8.19 % – of the greenhouse-gas balance for forests, however.

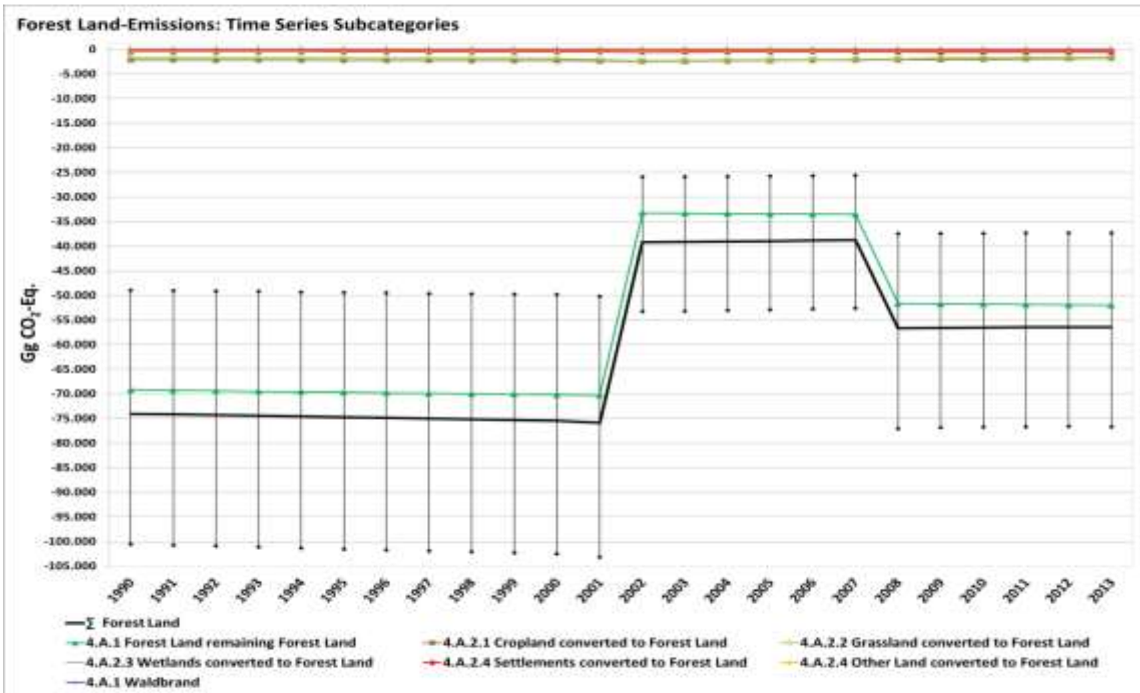

Figure 56: Greenhouse-gas emissions (total of CO_2, CH_4 and N_2O) [Gg CO_2-Eq.] as a result of land use and land-use changes in forests, 1990 – 2013, by sub-categories

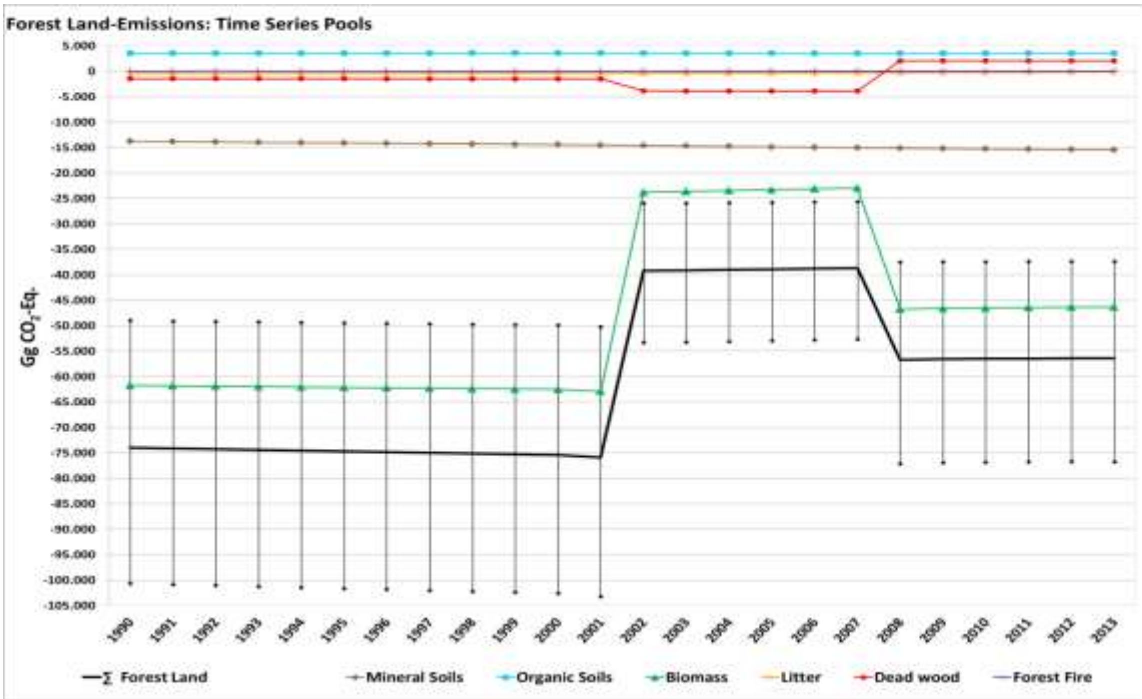

Figure 57: Greenhouse-gas emissions (total of CO_2, CH_4 and N_2O) [Gg CO_2-Eq.] as a result of land use and land-use changes in forests, 1990 – 2013, by pools

In the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006 Guidelines), and in the official reporting tables, in the "Common Reporting Format" (CRF), for the greenhouse-gas inventories sent to the Climate Secretariat, the category "Forest Land" is divided into "Forest Land remaining Forest Land" (forest that remains forest during the period covered by the report) and "Land converted to Forest Land" (new forest established, via afforestation or natural succession, on areas previously used for other land-use classes). It is important to note that relevant calculations are carried out on the basis of a 20-year transition time, and with a database beginning as of the year 1970 (cf. Chapter 6.3).

6.4.1.1 Forest Land remaining Forest Land (4.A.1)

Forest Land remaining Forest Land refers to the forest area that remains forest in the report year. It also includes areas that, after a 20-year period, are shifted from the category "Land converted to Forest Land" into the category "Forest Land remaining Forest Land". The category Forest Land remaining Forest Land differs from the total forest area in that it does not include Land converted to Forest Land, which is considered in a separate category (see Chapter 6.4.1.2).

6.4.1.2 Land converted to Forest Land (4.A.2)

Forest is established through succession, afforestation and reforestation; afforested areas start to accumulate carbon as soon as they are converted. Pursuant to the 2006 IPCC Guidelines, Land converted to Forest Land remains for the duration of the transition period of 20 years in the conversion category and is subsequently transferred into the "Forest Land remaining Forest Land" category.

It must be remembered that the C stocks of previous land uses are deducted following the conversion. Relevant information is provided in Chapters 6.4 through 6.9.

6.4.2 Methodological issues (4.A)

6.4.2.1 Data sources

The following data sources were used for determination of forest areas; determination of land-use changes that have occurred; estimation of the relevant emission factors for soil, biomass, litter and dead wood; for calculation of carbon stocks and stock changes at various times and over various periods; and for calculation of emissions from forest fires, drainage and mineralization:

- National Forest Inventory 1987 (Bundeswaldinventur; BWI 1987)
- National Forest Inventory 2002 (Bundeswaldinventur; BWI 2002)
- National Forest Inventory 2012 (Bundeswaldinventur; BWI 2012)
- Inventory Study 2008 (Inventurstudie; IS08)
- Datenspeicher Waldfonds (DSW)
- Forest Soil Inventory I (Bodenzustandserhebung im Wald I; BZE I)
- Forest Soil Inventory II (Bodenzustandserhebung im Wald II; BZE II)
- Soil-inventory data from the project BioSoil (BioSoil)
- GSE Forest Monitoring[91]: Inputs for national greenhouse-gas reporting (GSE FM-INT)

[91] GSE =GMES Services Elements
GMES = Global Monitoring for Environment and Security

- Official topographic-cartographic information system (Amtliches Topographisch-Kartographisches Informationssystem; ATKIS®)
- CORINE Land Cover (CLC)
- Soil map for the Federal Republic of Germany 1:1,000,000 (Bodenübersichtskarte der Bundesrepublik Deutschland; BÜK 1000)
- Forest-fire statistics of the Federal Republic of Germany

6.4.2.1.1 National Forest Inventory, Inventory Study 2008 and Datenspeicher Waldfonds

The National Forest Inventory surveys the state of forests, and of forest production potential, on a large scale throughout Germany, using a standardised sampling procedure. The National Forest Inventory is a terrestrial sampling inventory that uses permanently marked sample points in a 4 km x 4 km basic grid whose resolution, at the request of the Länder, has been increased on a regional basis[92]. The first National Forest Inventory (BWI 1987) covered only the territory of the Federal Republic of Germany, in its pre-1990 borders, and West Berlin. It was carried out in the period 1986 to 1989 (sample year 1987). The second National Forest Inventory (BWI 2002) was carried out in the period 2001 to 2003 (sample year 2002), as a repeat inventory in the old German Länder and as a first inventory in the new German Länder (BMVEL, 2001; BMELV, 2005). The data of the third National Forest Inventory (BWI 2012) are now available. That inventory was carried out from 2011 through 2012 (sample year 2012), as a repeat inventory, throughout the entire national territory. The BWI 2012 provides current data, as of the beginning of the Kyoto Protocol's second commitment period, on the condition of forests and the ways they are changing.

In 2008, data on the state of forests were collected on a sub-sample area of the National Forest Inventory that consisted of an 8 km x 8 km grid. In the main, the methods used for that so-called "2008 Inventory Study" (Inventurstudie 2008; IS08) are the same as those used for the National Forest Inventory (SCHWITZGEBEL et al. 2008, BMELV 2010).

The Datenspeicher Waldfonds (DSWF) database contains complete-coverage forestry-management data for the territory of the former GDR through 1993. Those data were collected at periodic intervals, annually revised in connection with growth models and updated in keeping with completion and change reports of that country's forest operations (BMELF, 1994).

6.4.2.1.2 Forest Soil Inventory (Bodenzustandserhebung im Wald – BZE)

Carbon emissions from forest soils have been estimated via the stock-changes method (2006 IPCC Guidelines). To that end, data from the soil surveys BZE I and BZE II were used. The Forest Soil Inventory I (BZE I) was carried out from 1987 to 1992, while the Forest Soil Inventory II (BZE II) was carried out from 2006 to 2008. In both inventories, samples were taken of both total organic layer, referred to in the following as "litter", pursuant to IPCC (2003), and of mineral soils. The data for the inventories were collected by the Länder.

In the BZE I (WOLFF & RIEK 1996) and BZE II (WELLBROCK et al. 2006), forest soils throughout Germany were sampled within an 8 km x 8 km grid. In the sampling procedure, at each grid point, eight satellite samples were taken, within a 10 m radius around a central excavation with an exposed soil profile. For the BZE I, there were 1800 grid points; for the BZE II, there were 2000. The primary reason for the increase in the number of grid sample

[92] Further information: http://www.bundeswaldinventur.de

points, from one inventory to the next, is that for the second it became possible to access areas which had been closed for the first (for which no access permits were available; for example, various former military exercise grounds were opened up).

For the most part, corresponding grid points for the two inventories all lay, in each case, within a 30 m radius. For some 400 points, a systematic grid shift with respect to the BZE I occurred.

For the BZE I, a database is now available with some 1800 points for which carbon stocks for litter and the mineral soil (0 – 30 cm) have been calculated (WOLFF & RIEK 1996), and the Länder have nearly completed transmitting BZE II survey data to a joint national database. For the BZE II, data from some 1,800 grid points are available for calculation of carbon stocks. Relevant analyses, and assessment in co-operation with Länder experts, have not yet been completed.

6.4.2.2 Biomass (CRF Table 4.A)

6.4.2.2.1 Forest Land remaining Forest Land

The changes in biomass carbon stocks are calculated with the stock-difference method, a Tier 2 method (Equation 2.8, IPCC 2006 Guidelines). With that method, one obtains an average country-specific emission factor for the time periods between different relevant years for which data sources are available. This leads to an IEF for the period prior to 2002, expressing the average biomass change between the BWI 1987 and the BWI 2002 in the old German Länder, and between the DWSF and the BWI 2002 in the new German Länder; an IEF for the period 2002 through 2008, expressing the average biomass change between the BWI 2002 and the IS08 (2008); and an IEF for the period 2008 through 2012, expressing the average biomass change between the IS08 and the BWI 2012 for Germany as a whole. As a result, the relevant biomass changes are adjusted between the years 2001/2002 and 2007/2008, in a manner leading to the "jumps" referred to above (cf. Chapter 6.4.1, Figure 50). The changes are due to changes in wood use, which increased in the inventory period 2002 through 2008 and decreased in the period 2008 through 2012.

For the old German Länder, and for the period until 2002, relevant data are available from two national forest inventories (referenced to the dates 1 October 1987 and 1 October 2002). Between the BWI 1987 and the BWII 2002, C stocks in biomass increased by 1.26 MgC ha^{-1} a^{-1} in the forests of the old German Länder. The increase in stocks is a result of low use, in comparison to growth. For the new German Länder, data from the BWI 2002 were compared with data from the Datenspeicher Waldfonds (DSWF) database, given the lack of an initial inventory comparable to the 1987 BWI. The comparison showed a net C-stock increase of 1.83 MgC ha^{-1} a^{-1}. The emission factor for Germany as a whole, for the period in question, is 1.43 MgC ha^{-1} a^{-1}. For the period from 2002 through 2008, data for stock-change calculations throughout Germany are available from the BWI 2002 and the Inventory Study 2008 (IS08). On the basis of that data, a C-stock increase of 0.43 MgC ha^{-1} a^{-1} was calculated for Germany. For the period 2008 through 2012, equivalent to the first commitment period under the Kyoto Protocol, the data of the IS08 and of the BWI 2012 have been used for a more-extensive calculation of the carbon-stock change. The change amounts to 1.03 MgC $ha^{-1}a^{-1}$. That value was adopted for the year 2013 as well.

Nonetheless, the sink effect of forests under forest management decreased significantly in 2002. The relevant reasons include a near doubling of the annual cut. In the first inventory period (1987 – 2002), for example, an average of about 47.9 million m³ (cubic meters of standing timber) were harvested per year in the old German Länder, while some 89.0 million m³ were harvested in the 2002 – 2008 inventory period. Despite the increases in the annual cut, and the resulting CO_2 emissions, the sum total of such emissions is still more than offset by the relevant CO_2 removals. With the data of the BWI 2012, it has been possible to show that forests regained a major sink status as of 2008. This is due to new decreases in wood harvesting.

Logging statistics for Germany as a whole show a similar trend – although they differ from forest-inventory values (cf. DIETER & ENGLERT 2005) – with an average of 39 million m³ (Efm = cubic metres of harvested timber, i.e. with bark and cutting losses deducted)[93] in the period 1991 – 2001, an average of 57 million m³ (Efm) in the period 2002 – 2007 and an average of 53 million m³ (Efm) in the period 2008 – 2012. Figure 59 shows the relationship between wood-harvest statistics and biomass changes. The quality of logging-statistics data is poor however, since many subsets of the data are based on experts' assessments. "In light of the results of the National Forest Inventory, and of other estimates presented above, the figures in the official logging statistics can no longer be credibly defended. This applies both to statistics on quantities of timber cut and to various aggregated subsets of the statistics" (DIETER & ENGLERT 2005, p. 7). For this reason, the logging statistics are unsuitable as a data source for the national inventory.

Figure 58 shows the carbon stocks for the four inventory dates. The data for 1987 and 1993 have been derived from the BWI 1987 or the DSWF; data for 2002 have been taken from the BWI 2002; data for 2008 have been derived from the IS08; and data for 2012 have been derived from the BWI 2012. These figures also highlight the increase in forest carbon stocks, even though they include only stocks on forest land remaining forest land (and not land converted to forest land).

Overall, the forests of the Federal Republic of Germany are thus a net sink for carbon.

[93] The wood mass in standing trees is given in cubic metres of standing timber. A cubic meter of harvested timber is equivalent to a cubic meter of standing timber less the losses incurred in wood harvesting and grading.

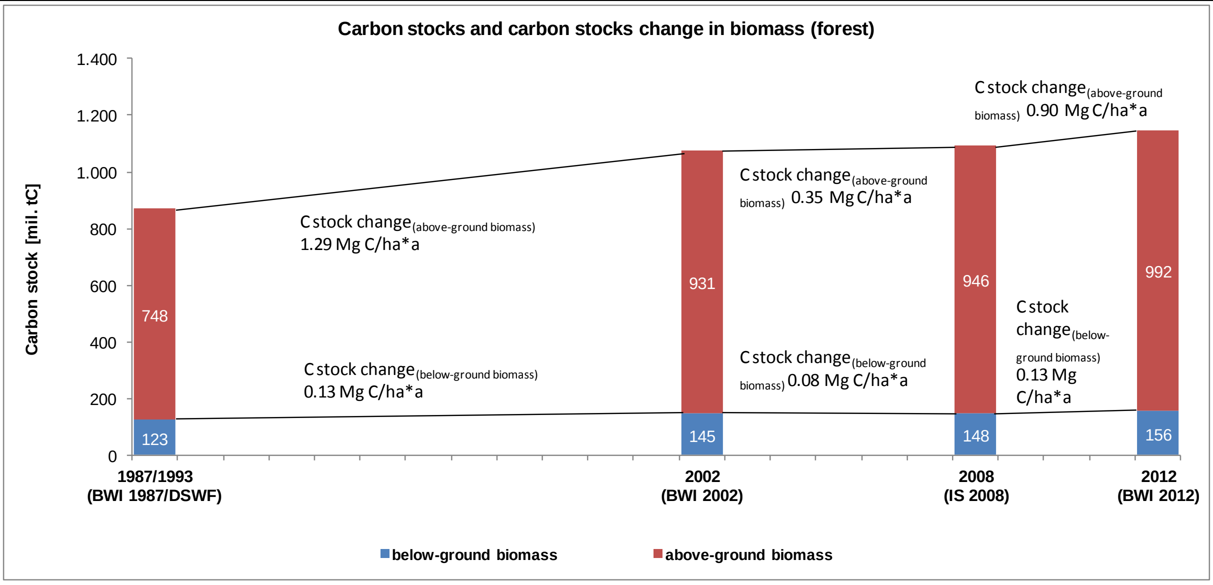

Figure 58: Carbon stocks and carbon-stock changes in below-ground and above-ground biomass, in forest, in the years 1987/1993, 2002, 2008 and 2012 [Veränderung = change; oberirdisch = above-ground; unterirdisch = below ground]

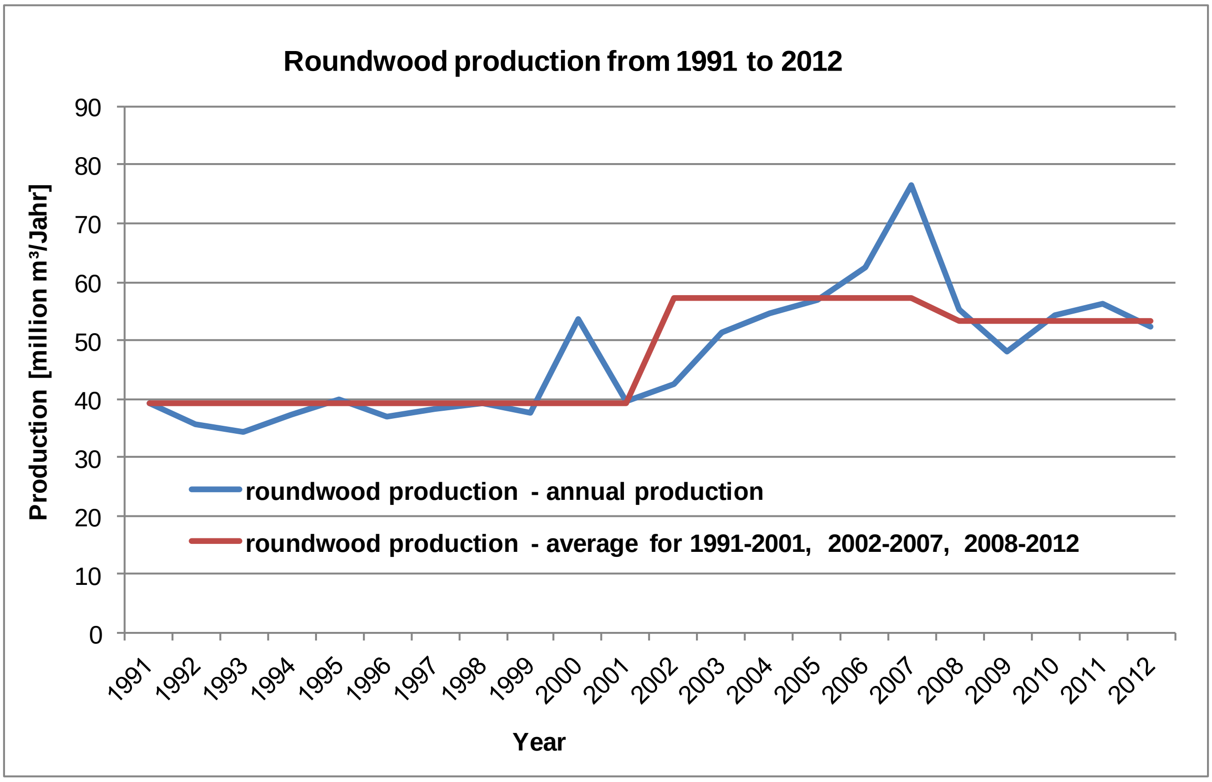

Figure 59: Raw-wood production in forests, pursuant to logging statistics of the Federal Statistical Office, annually and for the periods 1991 through 2001, 2002 through 2007 and 2008 through 2012 [jährlich = annual; Durchschnitt = average]

6.4.2.2.2 Land converted to Forest Land

The changes in biomass carbon stocks are calculated with the Tier 2 method given by Formula 2.16 of the *2006 IPCC Guidelines*. In that approach, the stock changes are determined as the difference between the biomass stocks prior to the conversion and after the conversion (cf. also Chapter 6.1.2.3).

To obtain emission factors for Land converted to Forest Land, an individual-tree calculation was carried out on the basis of the BWI 1987, BWI 2002 and BWI 2012 inventories. For the period through 2002, only trees in the old German Länder were taken into account, since the BWI 1987 inventory was carried out only there. As of the year 2002, calculations were carried out for Germany as a whole. The carbon stocks were calculated for each area on which conversion from a given land use to forest land took place, and then all the resulting stocks were combined within the "Land converted to Forest Land" category. The stocks of earlier-use categories were deducted – and thus taken into account.

For the the new German Länder in the period 1990 through 2002, it was not possible to derive wood stocks for Land converted to Forest Land directly from comparison of two inventories. As a result, the relevant values for the old German Länder were used for that period.

The biomass stocks at the end of the vegetation period in 2002 and in 2012 represent the increase in biomass stocks throughout the entire period under consideration since 1987. That stock increase has been linearly interpolated in the periods 1990 through 2002 and 2002 through 2012. The data of the IS08 are unsuitable for calculation of biomass on land converted to forest land, since that survey did not cover land converted to forest land. For the period 1990 through 2002, the annual C-stock increase is 3.40 MgC ha^{-1} a^{-1}; for the period 2002 through 2012, the annual increase is 3.64 MgC ha^{-1} a^{-1}. It must be remembered that afforested areas remain in this land-use category for 20 years. On the areas added each year, the C-stock losses from previous uses must be taken into account in the year in which conversion takes place; those losses are immediately assessed as emissions.

6.4.2.2.3 Derivation of individual-tree biomass

The above-ground biomass is estimated by means of biomass functions derived from the data of the National Forest Inventory. Further information is provided in KÄNDLER & BÖSCH (2013) and in Chapter 6.4.2.2.4. The below-ground biomass is also derived via biomass functions. The functions used for this purpose are existing functions that effectively represent the circumstances prevailing throughout the country (cf. Chapter 6.4.2.2.5).

Carbon stocks in the old German Länder as of 1987 were calculated on the basis of data from the BWI 1987 (some 230,000 measured trees). For the new German Länder, data on forest-management plans through 1993 are available in aggregated form, in the Datenspeicher Waldfonds database, that can be used for calculations of C stocks. The BWI 2002 survey, in which some 377,000 trees were measured, provides the database for the 2002 sampling year for Germany. The BWI data have been supplemented with repeat-survey data for some 83,000 trees, from the Inventory Study 2008. The present submission now makes use of an additional set of data that became available at the end of the first commitment period under the Kyoto Protocol – the data of the BWI 2012, covering some 537,000 trees. These data sources provide a good basis for calculation of the estimated C-stock changes – good enough, in fact, to make the stock-difference method, Equation 2.8 *IPCC 2006 Guidelines*) preferable to the biomass-gain-loss method.

6.4.2.2.4 Conversion into above-ground individual-tree biomass

The some 1,600 trees covered by the study of KÄNDLER & BÖSCH (2013) included only the species spruce, pine, beech and oak. All other tree species, with the exception of soft hardwoods, were included in those four species groups. If the study had also included the soft hardwoods in the beech tree-species class, and then applied the pertinent functions and coefficients, it would have considerably overestimated the biomass of that tree-species group. For this reason, for soft hardwoods a more suitable biomass function of the same type was fitted, with the help of "pseudo-observations" based on the tables in GRUNDNER & SCHWAPPACH (1952).

The biomass functions based on tree-species groups can be divided into three parts:

- Trees >= 10 cm DBH
- Trees >= 1.3 m height and < 10 cm DBH, and
- Trees < 1.3 m height

Trees that are < 1.3 m in height (and for which no DBH can be measured) cannot be usefully differentiated in accordance with the five aforementioned tree-species groups. For this reason, such trees are differentiated only in terms of whether they are coniferous or broadleaf trees. In transition areas, the functions are smoothed with the help of statistical procedures, in order to prevent jumps between the functions wherever possible.

The following section presents the functions used for deriving above-ground biomass from the National Forest Inventory data, as well as the functions' coefficients, broken down by tree-species groups.

Trees with at least 10 cm DBH

Equation 18

$$Y_{BIOM_0} = b_0 e^{b_1 \frac{BHD}{BHD+k_1}} e^{b_2 \frac{D03}{D03+k_2}} H^{b_3}$$

Y_{BIOM_0} = Above-ground biomass in kg per individual tree,

$b_{0,1,2,3}$ and $k_{1,2}$ = Coefficients of Marklund function
DBH = Diameter at breast height in cm
D03 = Diameter in cm at 30% of tree height
H = Tree height in m

Table 278: Coefficients of biomass function for trees >= 10 cm DBH

Tree species	b_0	b_1	b_2	b_3	k_1	k_2	RMSE%
Spruce	0.75285	2.84985	6.03036	0.62188	42.0	24.0	11.2
Pine	0.33778	2.84055	6.34964	0.62755	18.0	23.0	15.6
Beech	0.16787	6.25452	6.64752	0.80745	11.0	135.0	18.8
Oak	0.09428	10.26998	8.13894	0.55845	400.0	8.0	12.1
Soft hardwoods	0.27278	4.19240	5.96298	0.81031	13.7	66.8	50.0[94]

[94] For these function, no figure for RMSE% is available. Therefore, the IPCC default value of 50% has been used.

Trees > 1.3 m height and < 10 cm DBH

Equation 19

$$Y_{BIOM_0} = b_0 + \left(\frac{b_s - b_0}{d_s^2} + b_3(BHD - d_s)\right) BHD^2$$

Y_{BIOM_0} = Above-ground biomass in kg per individual tree,

$b_{0,s,3}$ = Coefficients of the function
BHD = Diameter at breast height in cm
d_s = Diameter-validity boundary for this function = 10 cm

Table 279: Coefficients of biomass function for trees >= 1.3 m height and < 10 cm DBH

Tree species	b_0	b_s	b_3
Spruce	0.41080	26.63122	0.01370
Pine	0.41080	19.99943	0.00916
Beech	0.09644	33.22328	0.01162
Oak	0.09644	28.94782	0.01501
Soft hardwoods	0.09644	16.86101	-0.00551

Trees < 1.3 m height

Equation 20

$$Y_{BIOM_0} = b_0\, H_1^b$$

Y_{BIOM_0} = Above-ground biomass in kg per individual tree,

$b_{0,1}$ = Coefficients of the function

H = Tree height in m

In the National Forest Inventory, heights of trees shorter than 1.3 m are recorded only in terms of two basic classes: 20 – 50 cm and 50 – 130 cm, and thus the mid-range values of these classes, 35 cm and 90 cm, have been used in the function as standard values.

Table 280: Coefficients of biomass function for trees < 1.3 m height

Tree species	b_0	b_1
Spruce	0.23059	2.20101
Beech	0.04940	2.54946

No inventory data were available for the new German Länder for the year 1990. The only available data source of some relevance is the Datenspeicher Waldfonds of 1993, which surveyed the stocks and the forested areas in the new German Länder via a consistent method. For this reason, in the present submission, as in past submissions, raw-wood stocks have been converted into biomass, using the methods described in BURSCHEL et. al (1993). In a first step of the relevant process, the raw-wood volume is multiplied by the applicable root percentage; this yields the pertinent below-ground volume. Then the raw-wood volume + the below-ground volume are multiplied by a volume-expansion factor. The product of that multiplication is then the applicable total tree-wood volume. The branch volume is obtained by subtracting the raw-wood volume and the below-ground volume from the tree-wood volume. Then, the various volumes are multiplied by the bulk density, using specific-bulk-density figures pursuant to PISTORIUS et. al (2006). All relevant values are listed in the following tables.

Table 281: Root percentages and bulk densities for conversion of Datenspeicher Waldfonds data

Tree species	Root percentage (up to 20 years old)	Root percentage (> 20 years)	RMSE%	Bulk density (raw wood + roots)	Bulk density (branch wood)	RMSE%
Spruce	100	30	50	0.38	0.49	18.8
Fir	100	25	50	0.36	0.49	22.7
Douglas fir	100	25	50	0.41	0.49	20.7
Pine	100	25	50	0.43	0.49	27.2
Larch	100	25	50	0.49	0.49	18.2
Beech	100	25	50	0.56	0.54	13.7
Oak	100	25	50	0.57	0.57	19.8
Hard hardwoods	100	25	50	0.56	0.57	15.0
Soft hardwoods	100	25	50	0.46	0.54	8.7

Table 282: Volume-expansion factors for conversion of raw-wood volume + below-ground volume into the tree-wood volumes of the Datenspeicher Waldfonds data

Tree species	0 through 20 years	21 through 40 years	41 through 60 years	61 through 80 years	81 through 100 years	101 through 120 years	121 through 140 years	141 through 160 years	> 160 years	RMSE%
Spruce	4	1.65	1.51	1.45	1.45	1.45	1.46	1.47	1.48	50
Fir	4	1.52	1.44	1.44	1.38	1.41	1.41	1.42	1.41	50
Douglas fir	4	1.65	1.51	1.45	1.45	1.45	1.46	1.47	1.48	50
Pine	4	1.51	1.42	1.40	1.36	1.34	1.34	1.34	1.33	50
Larch	4	1.51	1.42	1.40	1.36	1.34	1.34	1.34	1.33	50
Beech	4	1.69	1.47	1.41	1.38	1.39	1.39	1.38	1.39	50
Oak	4	1.58	1.41	1.39	1.37	1.35	1.34	1.35	1.34	50
Hard hardwoods	4	1.69	1.47	1.41	1.38	1.39	1.39	1.38	1.39	50
Soft hardwoods	4	1.69	1.47	1.41	1.38	1.39	1.39	1.38	1.39	50

No uncertainties are known for the root percentage and for the volume-expansion factor. For this reason, the IPCC default value of 50% has been used.

6.4.2.2.5 Conversion into below-ground biomass

The present submission introduces suitable biomass functions, based on reviewed articles, that address the need for consistency between the method used to derive above-ground biomass and that used to derive below-ground biomass, as well as the need for overall clarity and transparency. In recent years, a separate biomass function for derivation of below-ground biomass has been developed only for pine. All biomass functions chosen are of the form:

Equation 21

$$Y_{BIOM_u} = b_0 \; BHD_1^b$$

Y_{BIOM_u} = Below-ground biomass in kg per individual tree, b0,1 = coefficients of biomass function for below-ground biomass.

Table 283:

Tree species	b_0	Parameter	b_1	RMSE%	Region	Source
Spruce	0.003720	DBH [cm]	2.792465	34.6	Solling	BOLTE (2003)
Pine	0.006089	DBH [cm]	2.739073	26.3	Barnim	NEUBAUER & DEMANT (in preparation)
Beech	0.018256	DBH [cm]	2.321997	49.0	Solling	BOLTE (2003)
Oak	0.028000	DBH [cm]	2.440000	50.0[95]	Northeast France	DREXHAGE (2001), in BOLTE (2003)
Soft hardwoods (root biomass)	0.000010	DBH [mm]	2.529000	9.6	South Sweden	JOHANNSON (2012)
Soft hardwoods (root-stump biomass)[96]	0.000116	DBH [mm]	2.290300	15.9	South Sweden	JOHANNSON (2012)

The log functions available in the literature (cf. Figure 60) were intentionally not used. "Back transformation" of log error values, for further use in the error budget, either was unfeasible or, in cases in which the original measurements were available, yielded values as high as they were in the original scale units.

Like the Thünen Institute's own pine function (NEUBAUER & DEMANT, in preparation), the function provided by DREXHAGE (2001) in BOLTE (2003), for oak, is unique in the European context. The selected functions for beech and spruce cover a considerably broader area of DBH distribution, especially for larger diameters, than do the comparable studies of WUTZLER et. al. (2008) and WIRTH et. al.(2004a). The functions thus have a considerably smaller extrapolation region, which prevents upward "drifting" of biomass values (cf. Figure 60).

At the same time, the chosen functions for spruce and beech were derived through study of a small region, the "Solling" region. By contrast, the functions of WUTZLER et. al. (2008) and WIRTH et. al. (2004a) include data from a range of different, and geographically different, studies.

This comparison of the chosen functions for spruce, beech and soft hardwoods (in each case, the unbroken line in Figure 60) with functions from other publications shows that the chosen functions always produce conservative estimates of biomass stocks. The rates of change between two states are thus also small, by comparison to the corresponding figures produced by other functions. Since carbon accumulates in the pool of below-ground biomass, throughout the entire period covered by the report, the estimates of the sequestration rate are conservative.

[95] For these function, no figure for RMSE% is available. Therefore, the IPCC default value of 50% has been used.

[96] The mean RMSE% for both functions (root-stump biomass + root biomass) is 24.2%.

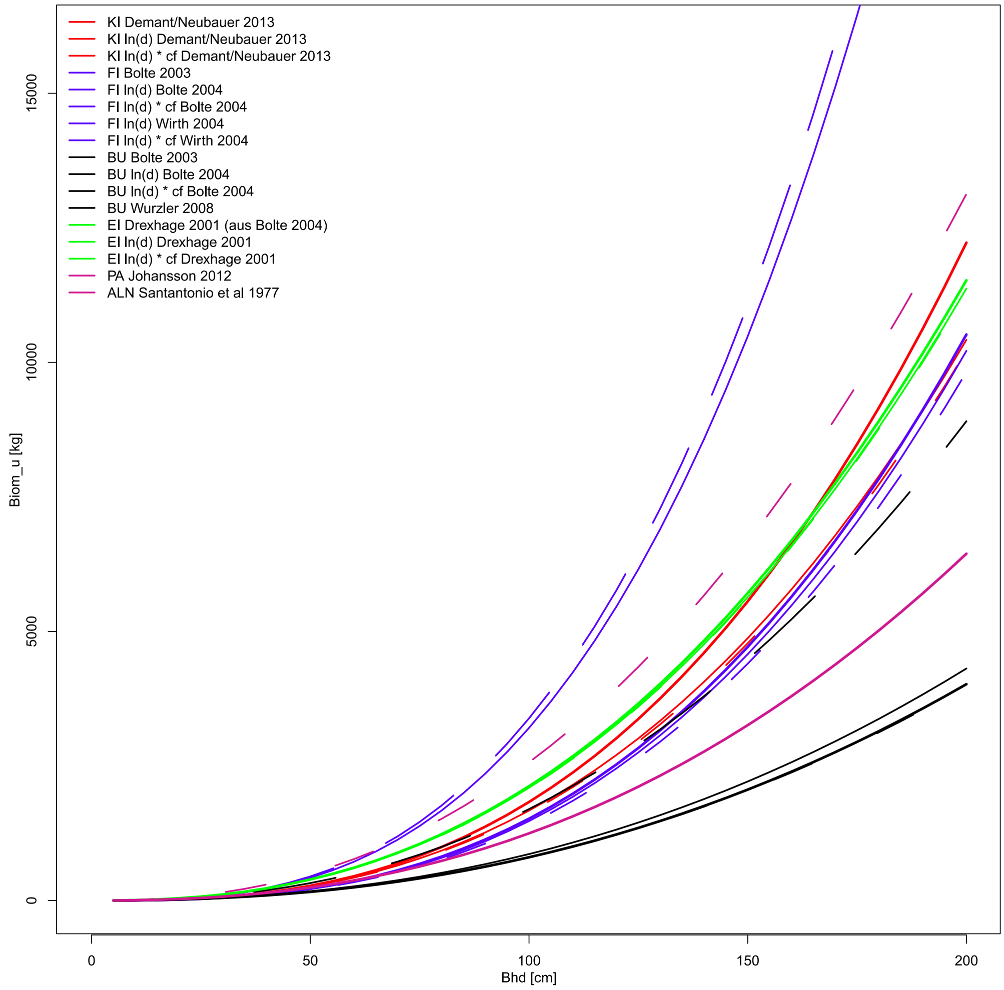

Figure 60: Comparison of different functions for derivation of below-ground biomass

6.4.2.2.6 *Conversion of individual-tree biomass to carbon*

A value of 0.5 has been applied for conversion of biomass into C stocks. WIRTH et al. (2004) report that the differences between compartments, within one and the same tree species, are larger than the differences between tree species. They obtain a range of 0.50 to 0.56 gC g^{-1} in conifers. The relative standard error for carbon content in wood is given by BURSCHEL et al. (1993) as 1 to 2 %; WEISS et al. (2000) use 2 %. Overall, therefore, 0.5 gC g^{-1}, with a relative standard error of ±2 %, seems appropriate as a good assumption for mean C content.

6.4.2.2.7 *State estimator for 1987, 2002, 2008 and 2012*

Some German Länder (states) use a sampling network with grids smaller than 4 x 4 km. In addition, some Länder have increased the density of their sampling networks between the inventories. For this reason, extrapolation to the level of the national territory has to take place in a stratified manner, using sampling strata with networks of homogeneous densities. This section presents the procedures for scaling up the values "raw-wood stocks", "biomass" and "carbon", in the framework of the stratified sampling plan, for given time periods. The relevant states for the years 1987, 2002, 2008 and 2012 were calculated. The up-scaling procedures for different domains (all of Germany, various regions (old/new Länder) and different LULUCF/ARD categories) are identical.

The National Forest Inventory is designed on a basis of cluster sampling. The smallest sampling unit is the cluster, with four cluster points (sample points). Along the boundaries of the inventory area, or of sampling strata, incomplete clusters, of varying sizes, will be found, i.e. the number of sample points (cluster points in forest and non-forest) within such clusters can vary between 1 and 4. For each cluster c located within a stratum *l*, the local density (*Y*) must be calculated first:

Equation 22

$$Y_{lc} = \frac{\sum_{m=1}^{M} I_{l,c,m} Y_{l,c,m}}{M_{l,c}}$$

where $M_{l,c}$ = number of sample points in cluster c in stratum *l*. The estimator of means, with respect to forest and non-forest, for stratum *l* is then obtained as follows:

Equation 23

$$\hat{\bar{Y}}_l = \frac{\sum_{c_l=1}^{C_l} M_{l,c} Y_{lc}}{\sum_{c_l=1}^{C_l} M_l}$$

The estimator of means for a given value, throughout all sampling strata ($\hat{Y}_{st}$), is the mean of the individual stratum estimators, weighted with the area proportions for the various strata:

Equation 24

$$\hat{\bar{Y}}_{st} = \sum_{l=1}^{L} \hat{\bar{Y}}_l \frac{\lambda(U_{l)}}{\lambda(U)}$$

The estimator of the total is obtained by multiplying the estimator of means throughout all strata by the total area *λ(U)*.

Equation 25

$$\hat{Y}_{st} = \hat{\bar{Y}}_{st} \lambda(U)$$

The (forest-) area-related mean estimator is defined as the quotient or ratio estimator ($\hat{R}_{st}$); it is obtained as follows:

Equation 26

$$\hat{R}_{st} = \frac{\hat{Y}_{st}}{\lambda(U_{Forest})}$$

6.4.2.2.8 Estimator for stock changes, in keeping with the "Stock-Change Method"

For calculation of the changes between two time points (the periods 1987-2002, 2002-2008 and 2008-2012), the "continuous forest inventory" (CFI) method was used, i.e. for up-scaling only those cluster points were used that were included at both times. The change estimate is thus based on the difference between the two status estimators. At the stratum level, the total change is estimated as follows:

Equation 27

$$\hat{G}_l = \hat{Y}_l^{(t_2)} - \hat{Y}_l^{(t_1)}$$

The total change throughout all strata for a given domain is estimated in the manner used in Equation 24. The estimated total change is calculated via Equation 25. The change in the area-related mean estimator is determined via:

Equation 28

$$\hat{G}_{R\,st} = \hat{R}_{st}^{(t_2)} - \hat{R}_{st}^{(t_1)}$$

6.4.2.2.9 Interpolation of time periods, to obtain annual-change estimates

The National Forest Inventory (BWI; Bundeswaldinventur) is carried out periodically. Consequently, annual rates of change – "emission factors" – have to be obtained via interpolation between two points in time. For the time periods between the inventories BWI 1987, BWI 2002, the Inventory Study 2008 and BWI 2012, linear interpolation was carried out at the level of the LULUCF and ARD classes. The emission factor EF for a LULUCF class is thus defined as the quotient of the area-related mean estimator and the number of years *a* within the relevant inventory interval:

Equation 29

$$EF = \frac{\hat{G}_{R\,st}}{a}$$

Consequently, Equation 27 is equivalent to Equation 2.5 of the 2006 IPCC Guidelines:

$$\Delta C = \frac{(C_{t_2} - C_{t_1})}{(t_2 - t_1)}$$

A linear trend was also chosen in cases in which change estimates had to be extrapolated into the future, beyond an inventory period.

6.4.2.3 Dead wood (CRF Table 4.A)

6.4.2.3.1 Forest Land remaining Forest Land

The changes in dead-wood carbon stocks are calculated with the stock-difference method, a Tier 2 method (Equation 2.19, IPCC 2006 Guidelines).

The C stocks in dead wood were calculated with data of the BWI 2002 (BMELV 2005) survey, the Inventory Study 2008 and the BWI 2012. The BWI 1987 did not include any surveys of dead wood, and thus no dead-wood data for that time are available. The terrestrial survey used for the BWI 2002 included only fallen dead wood with a thicker-end diameter of at least 20 cm, standing dead wood with a diameter of at least 20 cm at breast height (DBH), and trunks with either a height of at least 50 cm or a cut-surface diameter of at least 60 cm (BMVEL 2001). In keeping with requirements for climate reporting, in the Inventory Study 2008 and the BWI 2012 the survey threshold for dead-wood objects was reduced to a diameter of at least 10 cm at the thicker end (BMELV 2010). In all three forest inventories, trees were sub-divided into three main tree-species groups: conifers, deciduous trees (except for oaks) and oaks. In addition, dead wood was classified into a total of four decomposition-level categories (BMELV 2010, BMVEL 2001).

For purposes of reporting pursuant to the 2006 IPCC Guidelines, the applicable dead-wood-stock relationship between the 10 cm and 20 cm survey limits was determined from the data collected in the Inventory Study. Under the assumption that that relationship was the same at the time of the BWI 2002, the dead-wood stocks from the 10 cm survey limit upward were estimated for the year 2002. The biomass of the dead wood stocks from the BWI 2002, the Inventory Study (2008) and the BWI 2012, for the various relevant decomposition classes, was determined with the wood density figures pursuant to FRAVER et al (2002) for conifers, and with the wood density figures pursuant to MÜLLER-USING & BARTSCH (2009) for deciduous trees. To calculate the wood density of deciduous wood, the dead-wood objects in the deciduous (other than oak) and oak tree-species groups were combined. An overview of the biomass-expansion factors and their errors, broken down by tree-species classes and degrees of decomposition, is presented in Table 284.

Table 284: Biomass-expansion factors (BEF) and their errors (RMSE%) for the various tree-species classes and degrees of decomposition (NDH = conifers (Nadelbäume), LBH = deciduous trees (Laubbäume), EI = oak (Eiche))

Type of dead wood	Degree of decomposition		BEF	RMSE%	Source
NDH	1	Just died	0,372	17.2	FRAVER (2002)
NDH	2	Onset of decomposition	0,308	27.9	FRAVER (2002)
NDH	3	Advanced decomposition	0,141	35.5	FRAVER (2002)
NDH	4	Heavily rotted	0,123	25.2	FRAVER (2002)
LBH	1	Just died	0.58	12.1	MÜLLER-USING (2009)
LBH	2	Onset of decomposition	0.37	43.2	MÜLLER-USING (2009)
LBH	3	Advanced decomposition	0.21	33.3	MÜLLER-USING (2009)
LBH	4	Heavily rotted	0.26	65.4	MÜLLER-USING (2009)
EI	1	Just died	0.58	12.1	MÜLLER-USING (2009)
EI	2	Onset of decomposition	0.37	43.2	MÜLLER-USING (2009)
EI	3	Advanced decomposition	0.21	33.3	MÜLLER-USING (2009)
EI	4	Heavily rotted	0.26	65.4	MÜLLER-USING (2009)

The annual change of the C stock in dead wood was calculated using Equation 29 (2006 IPCC Guidelines, Equation 2.19). For the period 2002 through 2007, the change amounts to 0.0967 MgC ha^{-1} a^{-1}, and for 2008 through 2013 it amounts to -0.0519 MgC ha^{-1} a^{-1}. For all years in the period 1990 through 2001, the average change in dead-wood C stocks in the periods 2002-2007 and 2008-2012 was used, without change. It amounts to 0.0368 MgC ha^{-1} a^{-1}.

Equation 30

$$\Delta C_{FF_{DW}} = \frac{A * \left(B_{t_2} - B_{t_1}\right)}{T} CF$$

where:

ΔC_{FFDW} = Annual change in carbon stocks in dead wood, on forest land remaining forest land
A = Area of forest land remaining forest land
B_{t1} = Dead-wood stocks at time t_1 (beginning of the period) for forest land remaining forest land
B_{t2} = Dead-wood stocks at time t_2 (end of the period) for forest land remaining forest land
$T=(t_2-t_1)$ = Time period between the two estimates
CF = Carbon conversion factor (standard value = 0.5)

6.4.2.3.2 Land converted to Forest Land

The annual changes in C stocks in dead wood on land converted to forest land were calculated using Equation 2.19 of the 2006 Guidelines (IPCC, 2006). That equation is identical with the equation for calculating changes in dead-wood C stocks on forest land remaining forest land (cf. Equation 29). The dead-wood C stocks on land converted to forest land in 2012 (t2) are determined via the data of the BWI 2012. Those areas that at the time of the BWI 1987 were not forest areas count as land converted to forest land. Consequently, therefore, the dead-wood C stocks at time 1987 (t1) are assumed to be zero. The interval between the two time points is 25 years, which, for purposes of reporting under both the Convention and the Kyoto Protocol, leads to underestimation of the change in dead-wood C stocks. The method being applied is thus a conservative one. On land converted to forest land, the annual carbon-stocks change in dead wood amounts to 0.0344 MgC ha^{-1} a^{-1}.

Only the data of the BWI 2012 were available for determination of dead-wood C stocks on land converted to forest land. The Inventory Study 2008 did not survey land converted to forest land. With regard to dead wood, the BWI 2002 only included dead wood with a diameter of at least 20 cm at its thicker end (fallen dead wood) or with a DBH of at least 20 cm (standing dead wood). and the BWI 1987 did not survey dead wood at all.

6.4.2.4 Litter (CRF Table 4.A)

6.4.2.4.1 Forest Land remaining Forest Land

The changes in carbon stocks in litter are calculated with the stock-difference method, a Tier 2 method (Equation 2.19, IPCC 2006 Guidelines).

The calculation of C-stock changes in the soil and in litter is based on data from national forest-soil inventories (BZE I and BZE II; cf. Chapter 6.4.2.1.2, Grueneberg et al. 2014). A slight decrease in carbon stocks, amounting to -0.02 MgC ha^{-1} a^{-1}, occurred in the period from 1990 (BZE I) to 2006 (BZE II) (Grueneberg et al. 2014). That trend is assumed to be valid as well for the period 2007 to 2013. A detailed description of the method used to determine the carbon-stock change in litter is presented in Chapter 6.4.2.4.4.

6.4.2.4.2 Land converted to Forest Land

The carbon-stock changes were calculated in accordance with Equation 2.23 of the 2006 IPCC Guidelines (Tier 2). To use this method, one has to derive the annual rate of carbon-stock change. That rate is calculated from the average litter stocks in forests, under equilibrium conditions, and the transition period that is required for litter stocks to develop following afforestation.

Calculations relative to the litter ground cover were carried out with the status data of the BZE I and BZE II Forest Soil Inventories. According to those calculations, the mean carbon stocks in litter, referenced to 1990 (BZE I), were 19.0 MgC ha^{-1}, and, referenced to 2006 (BZE II), 18.8 MgC ha^{-1}. It was found that the average litter stocks in forests also exhibited a slight trend. The average litter stocks are being adjusted in keeping with that trend. For the period 1991 to 2005, the mean carbon stocks in litter are obtained via interpolation; for the period as of 2007 they are obtained via extrapolation and used as a basis for calculating afforestation areas (cf. Table 285). A description of the method used to derive carbon stocks in litter is presented in Chapter 6.4.2.4.3, Table 285).

Table 285: Emission factors for litter in the land-use categories with conversion to Forest Land (Land converted to Forest Land)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
IEF [MgC ha^{-1}]	0.4750	0.4747	0.4744	0.4741	0.4738	0.4734	0.4731	0.4728	0.4725	0.4722	0.4719
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
IEF [MgC ha^{-1}]	0.4716	0.4713	0.4709	0.4706	0.4703	0.4700	0.4697	0.4694	0.4691	0.4688	0.4684
Year	**2012**	**2013**									
IEF [MgC ha^{-1}]	0.4681	0.4678									

It was assumed that in the transition period, the resulting average carbon stocks take 40 years to form in litter. That figure is confirmed by standard values for carbon storage in litter, and by standard values for the time periods required for a new balance to form pursuant to PAUL et al. (2009) and the Good Practice Guidance, Table 3.2.1 (IPCC (2003)). In Table 3.2.1, the warm, temperate climate zone is assumed to be moist in Germany, and an applicable mean value is obtained from the values for deciduous forests and coniferous forests. The annual carbon-stock increase in litter is obtained by dividing the mean carbon stocks for the year in question by the number of years required for those mean carbon stocks to form.

The afforestation areas were not further subdivided into the classes "natural regeneration" and "human induced" (cf. Chapter 11.4.1).

6.4.2.4.3 Derivation of carbon stocks in litter

Litter was sampled at the relevant inventory points. This was accomplished by taking mixed samples at satellite points, using sampling frames of various sizes. In keeping with the GPG 2003, litter was considered to comprise the dead organic surface layer, along with the L, Of and Oh horizons. Organic carbon concentrations in the litter were measured via comparable methods. The following relationship is relevant: total carbon (C_{ges}) is equal to organic carbon (C_{org}) ([C_{ges}]=[C_{org}]). In each case, the carbon stocks in litter are calculated from the area of the sampling frame, and from the weight and organic concentration of the relevant litter. A description of the methods used for relevant sampling and analysis is presented in Wellbrock et al. 2006 and KÖNIG et al. 2005.

All points available from the BZEI and BZE II surveys, along with information as to the forest type concerned in each case, entered into calculation of litter carbon stocks. All values that were either smaller or larger than twice the standard deviation ($x \pm 2\sigma$) were considered to be outliers and were deleted. From the values of the remaining data points for the BZE I (n = 1629) and BZE II (n = 1542) surveys, it was possible to calculate carbon stocks separately for deciduous, coniferous and mixed forest (cf. Table 286). The mean C stocks given by the two inventories were calculated as a weighted mean from the carbon stocks for the three forest types concerned. The applicable weights were obtained from the forest types' area shares of the total forest area, as given by CORINE land-use data for 1990 and 2006, and from the regional densities of the inventory networks. The mean C stocks in the samples were 19.0 ± 0.3 MgC ha^{-1}, for BZE I, and 18.8 ± 0.3 MgC ha^{-1}, for BZE II (Grueneberg et al. 2014). These values serve as the basis for calculating CO_2 emissions from litter in connection with deforestation (cf. Chapter 11.3.1.1.4) and carbon sequestration in litter in connection for afforestation (cf. Chapter 6.4.2.4.2).

Table 286: Carbon stocks in litter in German forests, as determined in the BZE I and BZE II inventories, along with the pertinent standard error (Grueneberg et al. 2014)

Forest type	Carbon stocks (BZE I) [Mg C/ha]	Carbon stocks (BZE II) [Mg C/ha]
Deciduous forest	8.35 ± 0.37	6.78 ± 0.30
Mixed forest	17.94 ± 0.63	14.99 ± 0.70
Coniferous forest	23.75 ± 0.44	25.23 ± 0.49
Total forest	**19.05 ± 0.30**	**18.83 ± 0.32**

6.4.2.4.4 Derivation of carbon-stock changes in litter in the period from 1990 (BZE I) to 2006 (BZE II)

The sampling plots entering into calculation of carbon stocks were analysed as unpaired samples. With a two-sided t-test for unpaired samples, it was tested whether the carbon stocks (which had been logarithmised) at the two inventory times differed. Each sampling plot was assigned a weight consisting of the area percentage for the relevant stratum and the regional network density. The average difference was -0.02 ± 0.02 MgC ha^{-1} a^{-1} (Grueneberg et al. 2014). The value did not deviate significantly from zero.

For Land converted to Forest Land, annually decreasing factors for litter accumulation were calculated from the C stocks given by BZE I / BZE II and the average difference (cf. Chapter 6.4.2.4.2 and Table 285).

6.4.2.5 Mineral soils (CRF Table 4.A)

6.4.2.5.1 Forest Land remaining Forest Land

The changes in carbon stocks in litter are calculated with the Tier 2 method given by Formula 2.25 of the 2006 IPCC Guidelines.

Carbon stocks, and carbon-stock changes, in mineral soils were up-scaled on the basis of the national forest soil inventories (BZE I and BZE II) (cf. Chapter 6.4.2.1.2), in accordance with Grueneberg et al. 2014. With the available data, the changes in mineral soils were calculated, with respect to both inventories. The relevant methods are described in detail in chapters 6.4.2.5.3 and 6.4.2.5.4. The resulting extrapolation for the entire national territory yielded a mean annual increase in carbon stocks in mineral soils of 0.41 ± 0.11 MgC ha^{-1}. It has been assumed that that trend continued for the period 2007 to 2012.

6.4.2.5.2 Land converted to Forest Land

For land converted to forest land, as with forest land remaining forest land, the carbon-stock change in litter is calculated via the Tier 2 method in accordance with Formula 2.25 of the 2006 IPCC Guidelines.

For Land converted to Forest Land, the carbon-stock changes in mineral soils were calculated in keeping with the procedure in Chapter 6.1.2.1. The calculated mean emission factors (implied emission factors) for the year 2012, which are summarised in Table 258 in Chapter 6.1.2.1, are oriented to annual carbon-stock changes in mineral soils in connection with land-use changes leading to Forest Land (Land converted to Forest Land), over a change period of 20 years.

6.4.2.5.3 Derivation of carbon stocks and carbon-stock changes

The carbon stocks and their changes were derived on the basis of inventory data (cf. Chapter 6.4.2.1.2, Grueneberg et al. 2014). Mineral soil was sampled at depths of relevance for the national inventory report; at most BZE points, this involved depth ranges of 0-5 cm, 5-10 cm and 10-30 cm. In a few cases, samples were taken on a horizon basis.

As part of sampling, the fine-earth bulk density (TRD_{fb}), the coarse-fragment content (GBA) and the organic-carbon concentration (C_{org}) were determined using comparable methods (KÖNIG et al. 2005). The fine-earth bulk density was determined via volume-adapted sampling, for different depth ranges; to some extent, estimated values based on soil profiles were used (WOLFF & RIEK 1996, WELLBROCK et al. 2006). Where fine-earth bulk-density data is lacking, existing relevant values from other inventories have been used. That procedure has also been applied to obtain coarse-fragment content values, which are needed for calculation of the TRD_{fb} and fine-earth stocks.

In carbonate-containing soils, the organic-carbon concentration (C_{org}) in fine soils was measured with respect to the inorganic-carbon concentration (C_{anorg}) ($[C_{org}] = [C_{ges}] – [C_{anorg}]$). In non- carbonate-containing soils, the relationship $[C_{org}] = [C_{ges}]$ applies.

The carbon stocks were calculated from the stocks for the individual depth layers. To that end, it was necessary first to translate horizon-based data into depth-layer sections. This was accomplished, in each case, by calculating the carbon stocks in a given depth layer, with stocks weighted in accordance with the thicknesses of overlapping sections and their carbon stocks.

An area-referenced approach, with strata formation, was used for calculation of carbon stocks and of their changes between the two inventory times. The basis for formation of area-relevant strata consisted of the 72 legend units used in the national soil map "Bodenübersichtskarte der Bundesrepublik Deutschland 1:1.000.000" (BÜK 1000). That source describes the dominant soil types, and parent material for soil formation, pursuant to the German soil system (AG BODEN 1994) and FAO legend (FAO 1990). Since the classes concerned differed in the number of sample points they contained, the various dominant soil units were aggregated into new dominant soil groups. This increased the basic totality for each class, thereby increasing the pertinent statistical significance. The groups formed were oriented to comparable soil types, to substrate type and parent material and to texture and lime content. All in all, 16 new dominant soil groups, with their pertinent parent material, were then available for area-referenced evaluation (cf. Table 287). The inventory plots were allocated to the dominant soil groups on the basis of data, collected in the inventories, relative to the parent material and any layering of that material, to soil type, to horizon sequences and to soil texture.

Table 287: Combined legend units on the basis of the BÜK 1000 soil map

Abb.	Dominant soil groups, by substrate type, soil texture and lime content
1	Nutrient-poor soils from dry, nutrient-poor sands
2	Various soils from sandy to loamy terrace or riverine deposits
3	Various soils from partly calcareous, loamy-clayey terrace or riverine deposits
4	Pseudo-gleyed soils from sandy to loamy sediments overlying boulder clay
5	Various soils from sandy sediments overlying boulder clay
6	Brown earths from nutrient-rich sands
7	Soils of loess areas
8	Various soils from scree overlying calcareous, marl and dolomite rock, alternating with terra fusca from silty-clayey redeposited products of limestone weathering
9	Brown earth and terra fusca from redeposited products of weathering of calcareous, marl and dolomite rock, and rendzina from limestone
10	Pelosol – brown earth / pelosol-pseudogley from weathering products of marl and clay rocks and calcareous layers
11	Brown earth from alkiline and intermediary magmatic rock
12	Brown earth from acidic magmatic and metamorphic rock
13	Brown-earth / podzolic soils from hard clayey and silty slates with fractions of greywacke, sandstone, siltstone, quarzite and phyllite
14	Podzols / brown earths from low-alkilinity quarzites, sandstones and conglomerates
15	Various soils alternating tightly with greywacke, clay slate, limestone, sandy, silty and clayey stones and loess-loam overlying various rocks
16	High-mountain soils from limestone, dolomite rock and silicate rock

For purposes of analysis, carbon-stocks data was available from a total of 1,865 plots from the BZE I inventory, and from 1,813 plots from the BZE II inventory (Grueneberg et al. 2014). With the exception of the data from two German Länder (states), the data were available mainly as paired samples, i.e. samples in which it was possible to correlate each BZE I point with exactly one BZE II point. The number of points that entered into the final calculation of carbon stocks and their changes was lower than the number suggested by the above figures, however. This was because some organic-soil areas were excluded, because a) it proved impossible to assign them to points of a dominant soil unit or b) because their stocks were seen to be implausible, on the basis of outlier analysis, and thus were rejected. For the analysis, the total sample, broken down by German Länder (states), was divided into a paired sample subset and an unpaired sample subset. In the paired sample subset, it proved possible to identify outliers via residual analysis. To that end, the carbon stocks for each dominant soil unit, at the various inventory time points, were compared via plotting in a linear regression. A relevant example is presented in Figure 61 (on the left). Studentised residuals were used to eliminate outliers that seemed inconsistent with the rest of the data (cf. Figure 61 (on the right)). In addition, a "hat matrix" was generated, for identification of "leverage"[97] points that represent outliers within the independent variable (cf. Figure 61 (right)) (WEISBERG 2005).

[97] Leverage is a dimensionless statistical indicator that shows how strongly a given individual value is influencing a given statistical regression model.

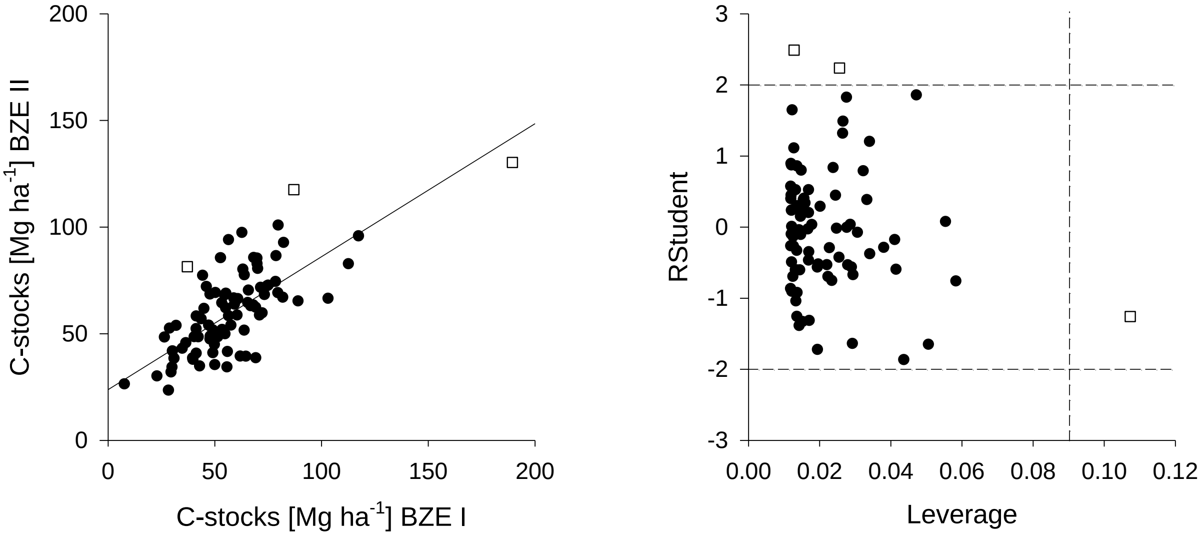

Figure 61: Regression between carbon stocks (0-30cm) as shown by BZE II data and the BZE I data (left), and outliers identified via residuals analysis with studentised residuals (middle) and "high-leverage" points (right), with regard to the example of the new dominant soil group

Since some Länder shifted the grid between the BZE I and BZE II inventories, the points for which assignment to a dominant soil group was possible were available as unpaired samples. Carbon stocks for those plots were calculated via formation of mean values for each dominant soil group. Outliers for each class were detected via double standard deviation (x ± 2 σ) and then removed. In addition, organic soils were excluded. Then, the mean carbon stocks for each dominant soil group were correlated with the relevant annual differences. After elimination of the outliers, via outlier analysis, a total of 1577 points from the BZE I inventory, and 1539 points from the BZE II inventory, were left. Of those, a total of 1075 points were available as paired samples.

To permit area-weighted calculation of carbon-stock changes, the forest areas on the new dominant soil groups were determined as percentage shares of Germany's total forested area. To that end, the CORINE land-use data were intersected with the BÜK 1000 data via a GIS. In each case, it proved possible to correlate a forest area with the mean carbon-stock change for a dominant soil group. That, in turn, made it possible to calculate the average annual change in organic carbon for Germany, taking account of the new dominant soil groups' shares of total relevant area.

6.4.2.5.4 Results of derivation of carbon stocks and carbon-stock changes

On the basis of the area-weighted approach, the carbon stocks in Germany's mineral soil, to a depth of 30 cm, amounted to 55.6 ± 3.4 MgC ha^{-1} at the time of the BZE I inventory, and to 61.8 ± 3.7 MgC ha^{-1} at the time of the BZE II inventories. Those figures translated into annual increases of 0.41 ± 0.11 MgC ha^{-1} (Grueneberg et al. 2014). A variance analysis (type III - ANOVA) showed that the differences between the two inventories were significant ($p<0.001$). Both the rate of change and the total stocks lie within a range that other authors have already estimated for central Europe. Estimates of annual carbon sequestration in the root zone range from 0.1 MgC ha^{-1} a^{-1} (NABUURS & SCHELHAAS 2002) to 0.9 MgC ha^{-1} a^{-1} (SCHULZE et al. 2000). Most of the values given in the literature are based on model-based up-scaling, and they take the soil's entire root zone into account (LISKI et al. 2002; DE VRIES et al. 2006). In comparison to those studies, the present effort was able to draw on considerably more measurement plots, arrayed within a finer grid. Those data represent a more valid sample, one that supports conclusions for Germany that are more reliable and that have a complete-coverage focus.

For nearly all dominant soil groups, carbon stocks, broken down by classes, were estimated to be higher at the time of the BZE II inventory than they had been at the time of the BZE I inventory (cf. Table 288). In addition, carbon stocks were higher in soils with high clay content than they were in soils with high sand content. The reasons for this are discussed in, for example, SIX et al. (2002) and BARITZ et al. (2010). Evaluation of the time series between the BZE I and BZE II inventories shows greater annual changes in carbon stocks especially in sandy dominant soil groups of the North German lowlands. For example, the annual relevant rate of change for the dominant soil units 1, 5 and 6 was greater than 0.6 MgC ha^{-1} a^{-1} (Grueneberg et al. 2014). On the other hand, PRIETZEL et al. (2006) put carbon sequestration, in the upper 30 cm, at 0.2 MgC ha^{-1} a^{-1} on sandy locations and at 0.4 MgC ha^{-1} a^{-1} on loamy locations. Smaller positive changes in carbon stocks, ranging between 0.1 and 0.6 MgC ha^{-1} a^{-1}, were found in over half of all classes formed. A marked decrease in C stocks, between the two inventory times, was seen in class 9.

Table 288: Carbon stocks at the time of the BZE I, and at the time of the BZE II, in the newly formed dominant soil units (Grueneberg et al. 2014)

	Carbon stocks (BZE I) [MgC ha^{-1}]			Carbon stocks (BZE II) [MgC ha^{-1}]		
DSU	**n**	**MV**	**SE**	**n**	**MV**	**SE**
1	201	52.8	1.6	187	65.5	6.8
2	56	60.5	2.6	62	65.0	4.9
3	20	67.3	3.2	25	68.1	2.4
4	105	66.4	1.8	87	64.1	4.5
5	77	33.4	1.6	75	52.8	2.2
6	34	24.6	1.6	34	43.7	1.8
7	126	55.8	1.5	109	63.0	2.2
8	110	76.3	2.4	106	79.1	0.8
9	36	77.1	4.9	43	68.3	1.0
10	55	56.7	2.1	63	60.8	0.8
11	39	51.3	3.2	39	54.6	0.9
12	187	59.5	1.7	163	62.5	2.2
13	222	54.7	1.4	233	60.1	4.1
14	245	50.5	1.2	257	55.3	3.2
15	30	51.8	2.9	30	49.0	0.9
16	34	84.4	6.2	26	104.5	0.5

(DSU = dominant soil units, n = number of soil samples, MV = mean value, SE = standard error)

6.4.2.6 Organic soils (CRF Table 4.A)

This chapter solely discusses CO_2 emissions from organic soils. Those emissions are entered in CRF Table 4.A, under "organic soils". The methods applied for N_2O and CH_4 greenhouse-gas emissions are described in Chapter 6.4.2.7.2. Those emissions are reported in CRF Table 4(II).

6.4.2.6.1 Forest Land remaining Forest Land

The areas covered by organic soils were determined via a georeferencing procedure, with overlaying of the "map of organic soils" ("Karte organischer Böden") and ATKIS® data. In the process, drained and non-drained organic soils are differentiated. For forest land areas, the organic soils area for the year 2013 is 335,848 ha, and 88 % of that area is drained. A detailed description of the method used to derive organic-soil areas is presented in Chapter 6.1.2.2.1.

The derivation of the relevant emission factor is described in Chapters 6.1.2.2.2 and 6.1.2.2.3. The implied emission factor for organic forest soils is -2.61 Mg C ha^{-1} a^{-1}. .

6.4.2.6.2 Land converted to Forest Land

In an approach similar to that used for Forest Land remaining Forest Land, a total of 88% of all Land converted to Forest Land, on organic soils, is assumed to be drained (cf. Chapter 6.1.2.1). The emission factor of -2.61 Mg C ha^{-1} a^{-1} is also used for organic soils under Land converted to Forest Land. Those annual emissions are being reported for all years since the relevant conversions. The manner in which greenhouse-gas emissions from organic soils are derived, for all land-use categories, is described in Chapter 6.1.2.2.

6.4.2.7 Other greenhouse-gas emissions from forests

6.4.2.7.1 Nitrous oxide emissions from nitrogen fertilisation (CRF Table 4(I))

No nitrogen fertilisation in forests takes place in Germany. In CRF Table 4(I), therefore, this activity has been marked "NO" (not occurring).

6.4.2.7.2 Drainage and rewetting of organic and mineral soils (CRF Table 4(II))

The derivation of greenhouse-gas emissions, from organic soils, related to drainage and rewetting is described, for all land-use categories, in Chapter 6.1.2.2. The CO_2 emissions for forests are entered in CRF Table 4.A and, in CRF Table 4(II), are marked "IE" (included elsewhere) (cf. also Chapter 6.4.2.6). The pertinent CH_4 and N_2O emissions, on the other hand, are included in CRF Table 4(II). They amount to 5.4 kg CH_4 ha^{-1} a^{-1} and 1.62 kg N_2O-N ha^{-1} a^{-1} for forests.

No rewetting of mineral soils in forests occurs; in CRF Table 4(II), that category is marked "NO" (not occurring).

6.4.2.7.3 Direct nitrous oxide emissions related to nitrogen mineralization and immobilization (CRF Table 4(III))

The manner in which direct N_2O emissions from mineralization and immobilization of mineral soils are determined is described in Chapter 6.1.2.1.2. The pertinent N_2O emissions are listed in CRF Table 4(III).

6.4.2.7.4 Indirect nitrous oxide emissions from cultivated soils (CRF Table 4(IV))

The manner in which indirect N_2O emissions related to losses of organic soil substance resulting from land-use changes and cultivation measures are determined is described, in summary form for all land-use categories, in Chapter 6.1.2.1.2. The pertinent N_2O emissions are listed in CRF Table 4(IV).

6.4.2.7.5 Forest fires (CRF Table 4(V))

While in other countries "prescribed burning" is an accepted method for clearing land or for managing ecosystems, no prescribed/controlled burning of biomass is carried out in

Germany's managed forests. In CRF-Table 4 (V), therefore, NO is entered in the category "Controlled Burning". In keeping with Germany's climatic situation, and with measures taken in Germany to prevent wildfires, such fires tend to be rather seldom. This conclusion is confirmed by relevant wildfire statistics (BLE, 2014) and their data on areas affected by wildfires (cf. Figure 62). The mean area affected annually by wildfires, in the period 1990 – 2013, was 802 ha. In some years, unseasonably high summer temperatures have resulted in larger burn areas. This was the case, for example, in 1996 and 2003. An unusually large burn area, about 4,908 ha, was measured in 1992, which had an extremely warm summer.

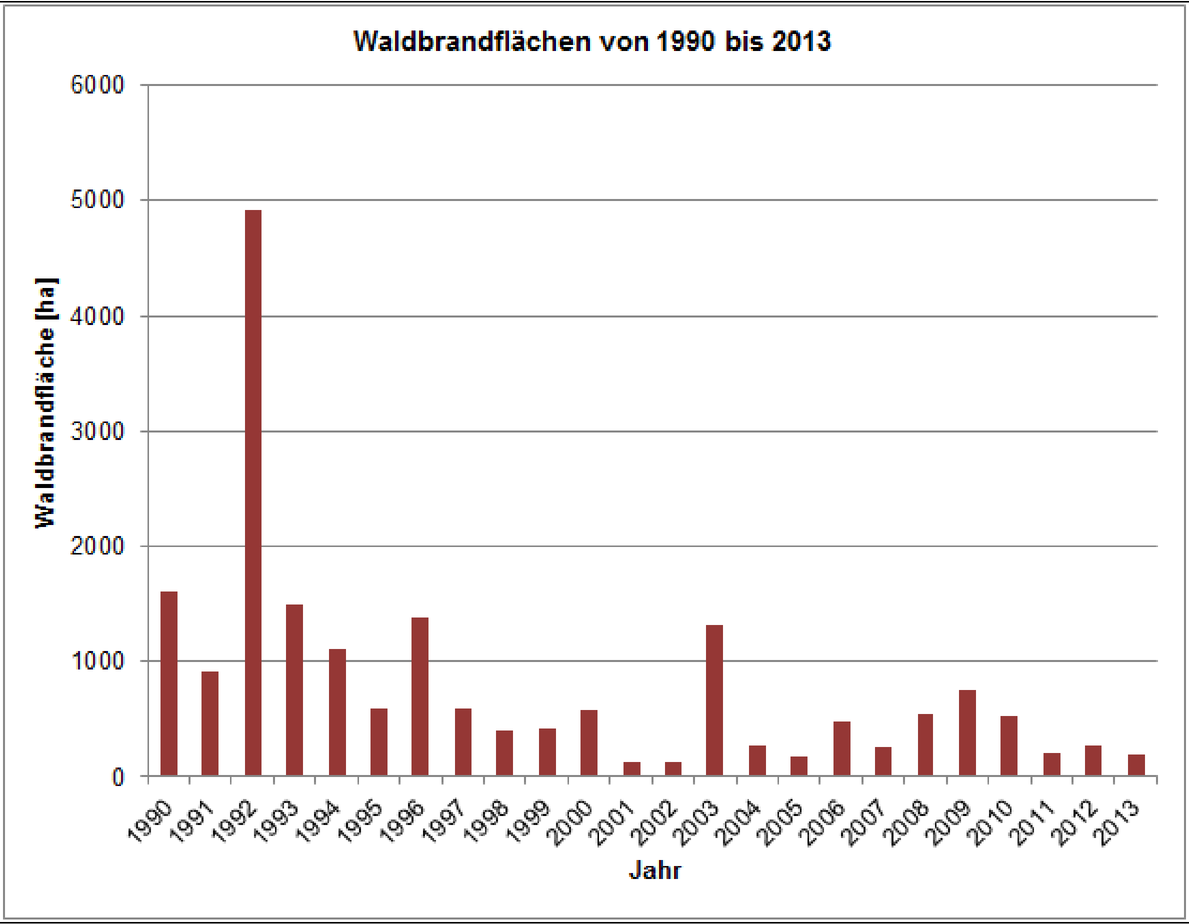

Figure 62: Areas affected by wildfires between 1990 and 2013 (pursuant to BLE, 2014) [area affected by wildfires [ha] / Year]

Along with CO_2, wildfires release a range of other greenhouse gases (CO, CH_4, N_2O and NO_x). The CO_2 emissions resulting from biomass combustion have already been taken into account as part of changes of biomass stocks (CRF Sector 4.A.1 Forest land remaining Forest Land), via the "stock-change method". For this reason, they are listed as "IE" (included elsewhere). Emissions of other greenhouse gases were calculated with Equation 31 (2006 IPCC Guidelines, Equation 2.27).

Equation 31

$$L_{fire} = A*B*C*D*10^{-6}$$

where:

L_{fire} = Quantity of greenhouse gas [t] released via fire

A = Wildfire burn area [ha]

B = Mass of fuel present on the relevant site (biomass) [kgTM ha^{-1}]

C = Combustion efficiency

D = Emission factor [g(kgTM)$^{-1}$]

The data on areas affected by wildfires in the period 1990 to 2013 have been taken from the wildfire statistics maintained by the Federal Agency for Agriculture and Food (BLE; Waldbrandstatistik – BLE 2014). In determination of relevant area sizes, no distinction is made between land converted to forest land and forest land remaining forest land. For this reason, emissions from land converted to forest land are reported with those from forest land remaining forest land and then entered as "IE" in CRF Tables 4(V). The data available for determination of biomass include the data for 1990 from the BWI 1987 and DSWF; the data for 2002 from the BWI 2002; the data for 2008 from the IS08; and the data for 2012 from the BWI 2012 . The mean above-ground biomass for each year was derived via linear interpolation between 1990, 2002, 2008 and 2012, and via extrapolation for the year 2013. Pursuant to the expert assessment carried out by KÖNIG (2007), 80 % of the wildfires in Germany remain on the ground surface and 20 % rise into tree crowns. In accordance with Table 2.6 (2006 IPCC Guidelines), a combustion efficiency (mass loss via direct combustion) of 0.15 was used for fires remaining on the ground surface, and an efficiency of 0.45 was used for fires rising into tree crowns. The emission factors for CH_4, N_2O, CO and NO_X were taken from Table 2.5 (2006 IPCC Guidelines).

Germany suffers relatively little wildfire damage in terms of burn area, and thus the relevant CH_4, N_2O, CO and NO_X gas emissions are low. With the exception of 1992, the pertinent CH_4 emissions range between 25 and 271 Gg, and the N_2O emissions range between 1.4 and 15.0 Gg. Those emissions levels were exceeded in 1992 (CH_4: 857 Mg, N_2O: 47.4 Mg, CO: 19,502 Mg, NO_X: 547 Mg), as a result of that year's unusually large burn area, which stemmed from that year's extremely warm summer. The complete time series for greenhouse gases resulting from wildfires is shown in Table 289.

Table 289: Greenhouse gases emitted as a result of wildfires, in the period 1990-2013

Year	Above-ground biomass [Mg ha^{-1}]	Wildfire burn area [ha]	Emitted gases [Mg]			
			CH_4	N_2O	CO	NO_X
1990	171	1,606	271	15.0	6,165	173
1991	174	920	158	8.7	3,594	101
1992	177	4,908	857	47.4	19,502	547
1993	180	1,493	265	14.7	6,033	169
1994	183	1,114	201	11.1	4,576	128
1995	186	592	109	6.0	2,472	69
1996	189	1,381	257	14.2	5,859	164
1997	192	599	113	6.3	2,582	72
1998	195	397	76	4.2	1,738	49
1999	198	415	81	4.5	1,844	52
2000	201	581	115	6.4	2,621	73
2001	204	122	25	1.4	559	16
2002	207	122	25	1.4	567	16
2003	208	1,315	270	14.9	6,137	172
2004	209	274	56	3.1	1,286	36
2005	210	183	38	2.1	863	24
2006	210	482	100	5.5	2,280	64
2007	211	256	53	2.9	1,214	34
2008	212	539	113	6.2	2,569	72
2009	214	757	160	8.9	3,646	102
2010	216	522	111	6.2	2,538	71
2011	218	214	46	2.6	1,051	29
2012	221	269	58	3.2	1,331	37
2013	223	199	44	2.4	994	28

6.4.3 Uncertainties and time-series consistency (4.A)

Various uncertainties have to be taken into account in calculation of carbon stocks. The actual uncertainties, however, can only be approximated, with the help of pragmatic approaches.

The uncertainties described in the following chapters enter into a total-error budget for the LULUCF sector that is presented in Chapter 19.4.4.

With regard to the uncertainties in the carbon-conversion factor, we call attention to Chapter 6.4.2.2.6.

When aggregated, error estimates (U) for values (1,..,*i…I*) propagate themselves in two different ways. When two values are added or subtracted, the error propagation is additive (cf. Equation 32).

Equation 32

$$U = \frac{\sqrt{\sum_i (U_i x_i)^2}}{\sum_i x_i}$$

where:

U	= Total uncertainty
U_i	= Uncertainty for target value
x_i	= Quantity of target value

On the other hand, when two values are multiplied or divided, the errors for the two values propagate themselves multiplicatively (cf. Equation 33).

Equation 33

$$U = \sqrt{\sum_i (U_i)^2}$$

6.4.3.1 Uncertainties in estimation of areas affected by land-use changes

In keeping with use of a sample-based system for determining land-use changes, the sampling errors for each LULUCF category can be calculated for each year (cf. Table 290). The sampling error is calculated in keeping with the formulae in Chapter 6.4.3.2. Once validation has been completed, all other error sources can be ruled out (cf. also Chapter 6.3.1.4). All areas have been entered significantly.

Table 290: Sampling error (SE), in %, in area estimation for LULUCF categories between 1990 and 2013

LULUCF category / year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Forest land remaining forest land	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.63	0.63	0.63	0.63	0.63
Conversion of forest land to cropland	8.07	8.07	8.07	8.07	8.07	8.07	8.07	8.07	8.07	8.07	8.07	7.90	7.76	7.67	7.60
Conversion of forest land to grassland	8.73	8.73	8.73	8.73	8.73	8.73	8.73	8.73	8.73	8.73	8.73	7.92	7.34	6.93	6.64
Conversion of forest land to woody grassland	7.89	7.89	7.89	7.89	7.89	7.89	7.89	7.89	7.89	7.89	7.89	7.53	7.29	7.14	7.08
Conversion of forest land to terrestrial Wetlands	31.94	31.94	31.94	31.94	31.94	31.94	31.94	31.94	31.94	31.94	31.94	29.17	28.16	28.24	28.93
Conversion of forest land to waters	26.81	26.81	26.81	26.81	26.81	26.81	26.81	26.81	26.81	26.81	26.81	25.41	24.31	23.46	22.81

LULUCF category / year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Conversion of forest land to settlements	8.48	8.48	8.48	8.48	8.48	8.48	8.48	8.48	8.48	8.48	8.48	8.15	7.89	7.70	7.55
Conversion of forest land to other land	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Conversion of cropland to forest land	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.51	4.43	4.37	4.32
Conversion of grassland to forest land	4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.10	3.98	3.89	3.82
Conversion of woody grassland to forest land	8.21	8.21	8.21	8.21	8.21	8.21	8.21	8.21	8.21	8.21	8.21	7.98	7.81	7.67	7.58
Terrestrial wetlands – conversion to forest land	16.87	16.87	16.87	16.87	16.87	16.87	16.87	16.87	16.87	16.87	16.87	16.67	16.52	16.41	16.34
Conversion of waters to forest land	25.03	25.03	25.03	25.03	25.03	25.03	25.03	25.03	25.03	25.03	25.03	24.88	24.74	24.62	24.53
Conversion of settlements to forest land	10.72	10.72	10.72	10.72	10.72	10.72	10.72	10.72	10.72	10.72	10.72	9.74	9.05	8.56	8.24
Conversion of other land to forest land	22.58	22.58	22.58	22.58	22.58	22.58	22.58	22.58	22.58	22.58	22.58	22.24	21.94	21.69	21.48

LULUCF category / year	2005	2006	2007	2008	2009	2010	2011	2012	2013
Forest land remaining forest land	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Conversion of forest land to cropland	7.57	7.44	7.38	7.37	7.18	7.28	7.32	7.39	7.46
Conversion of forest land to grassland	6.45	6.17	6.00	5.93	5.58	5.47	5.42	5.38	5.30
Conversion of forest land to woody grassland	7.08	6.95	6.95	7.08	6.91	7.16	7.28	7.44	7.63
Conversion of forest land to terrestrial Wetlands	29.93	24.78	25.37	27.12	25.45	24.82	25.21	25.63	25.52
Conversion of forest land to waters	22.34	21.27	20.41	19.74	18.37	17.96	17.73	17.53	17.21
Conversion of forest land to settlements	7.46	6.97	6.74	6.69	5.93	5.84	5.85	5.88	5.84
Conversion of forest land to other land	nd	nd	nd	nd	nd	nd	nd	nd	nd
Conversion of cropland to forest land	4.28	4.19	4.15	4.14	3.99	3.95	3.94	3.94	3.92
Conversion of grassland to forest land	3.78	3.62	3.53	3.48	3.25	3.21	3.20	3.19	3.17
Conversion of woody grassland to forest land	7.53	7.45	7.40	7.36	7.12	7.39	7.46	7.57	7.74
Terrestrial wetlands – conversion to forest land	16.31	16.09	15.95	15.87	15.38	15.10	15.05	15.02	14.86
Conversion of waters to forest land	24.44	22.95	22.43	22.57	21.39	20.65	20.67	20.76	20.40
Conversion of settlements to forest land	8.02	7.73	7.52	7.38	7.18	7.06	6.98	6.90	6.80
Conversion of other land to forest land	21.32	20.98	20.72	20.54	19.73	20.20	20.33	20.53	20.83

(nd = not defined[98])

6.4.3.2 Uncertainties in estimation of emission factors of living and dead biomass

Because biomass cannot be directly measured, a number of error sources enter into the process of deriving forest biomass and carbon stocks, and of deriving changes in forest biomass and carbon stocks. The errors in the biomass functions and in the carbon-conversion factor are listed and discussed in sections 6.4.2.2.4, 6.4.2.2.5 and 6.4.2.2.6. The errors in biomass-conversion factors for dead wood, broken down by tree species and degrees of decomposition, are given in Section 6.4.2.3.

[98] There are no areas in the land-use category Other Land

The errors related directly to tree-species groups are added to the uncertainties for the above-ground and below-ground biomass and then aggregated to yield an error figure for the total biomass. Because the biomass stocks at the first time point are subtracted from the stocks at the second time point, the uncertainty for the biomass change is obtained via addition. The error for the total biomass change is multiplied by the error for the carbon-conversion factor and by the sampling error. The sampling error is derived from the variance in the sample. The variance in the change of a ratio estimator (cf. equation 26) $v\left[\hat{G}_{R_{st}}\right]$ is defined as follows:

Equation 34:

$$v\left[\hat{G}_{R_{st}}\right] = v\left[\hat{R}_{st}^{(t_2)}\right] + v\left[\hat{R}_{st}^{(t_1)}\right] - 2\operatorname{cov}\left[\hat{R}_{st}^{(t_2)}, \hat{R}_{st}^{(t_1)}\right]$$

where:

$$\operatorname{cov}\left\langle \hat{R}_{st}^{(2)}, \hat{R}_{st}^{(1)} \right\rangle = \frac{1}{\hat{\hat{X}}_{st}^{(2)} \hat{\hat{X}}_{st}^{(1)}} \sum_{l=1}^{L} \left(\frac{\lambda(U_l)}{\lambda(U)} \right)^2 \frac{1}{n_{2,l}(n_{2,l} - 1)}$$

$$\sum_{x \in F_1 \cap s_2} \left(\frac{M(x)}{E(M(x))} \right)^2 \left(d_c^{(2)}(x) - \hat{\hat{d}}_l^{(2)} \right) \left(d_c^{(1)}(x) - \hat{\hat{d}}_l^{(1)} \right)$$

where

$$d_c^{(2)}(x) = (Y_c^{(2)}(x) - \hat{R}_{st}^{(2)} X_c^{(2)}(x))$$

and

$$\hat{\hat{d}}_l^{(2)} = \frac{1}{n_{2,l}} \sum_{x \in F_1 \cap s_2} \left(Y_c^{(2)}(x) - \hat{R}_{st}^{(2)} X_c^{(2)}(x) \right)$$

with $d_c^{(1)}(x)$ and $\hat{\hat{d}}_l^{(1)}$ having the corresponding values.

The following tables show the uncertainties for the individual error sources and for the resulting emission factor.

Table 291: Uncertainties in emission factors for living biomass on forest land remaining forest land, for various periods

FM 1987 – 2002	Error % (biomass conversion)						Error % (C)	SE %	RMSE%
Old German Länder	**spruce**	**pine**	**beech**	**oak**	**softwood**		**all**		
above ground	7.96	11.06	13.41	8.61	35.95	6.82	2.00	2.43	7.51
below ground	24.54	18.63	34.91	35.55	17.33	13.95	2.00	2.36	14.29
Emission factor						6.21	2.00	2.40	6.95
FM 1993 – 2002	**Error % (biomass conversion)**						**Error % (C)**	**SE %**	**RMSE%**
New German Länder	**spruce**	**pine**	**beech**	**oak**	**softwood**		**all**		
above ground	11.34	24.66	17.35	12.93	37.15	9.03	2.00	5.43	10.73
below ground	30.38	27.74	38.90	43.94	22.49	16.82	2.00	5.93	17.94
Emission factor						8.16	2.00	5.51	10.05
FM 2002 – 2008	**Error % (biomass conversion)**						**Error % (C)**	**SE %**	**RMSE%**
Germany	**spruce**	**pine**	**beech**	**oak**	**softwood**		**all**		
above ground	7.95	11.04	13.30	8.57	35.38	14.44	2.00	28.66	32.15
below ground	24.47	18.60	34.67	35.39	17.14	19.29	2.00	16.35	25.37
Emission factor						12.21	2.00	25.95	28.75
FM 2008 – 2013	**Error % (biomass conversion)**						**Error % (C)**	**SE %**	**RMSE%**
Germany	**spruce**	**pine**	**beech**	**oak**	**softwood**		**all**		
above ground	7.95	11.04	13.29	8.56	35.37	5.70	2.00	11.66	13.14
below ground	24.47	18.60	34.65	35.37	17.14	12.35	2.00	10.86	16.57
Emission factor						5.22	2.00	11.29	12.60

Table 292: Uncertainties in emission factors for living biomass on afforestation areas, for various periods

AR 1987 – 2002	Error % (biomass conversion)						Error % (C)	SE %	RMSE%
Old German Länder	**spruce**	**pine**	**beech**	**oak**	**softwood**		**all**		
above ground	11.23	15.62	18.80	12.10	50.00	12.14	2.00	7.39	14.35
below ground	34.60	26.30	49.00	50.00	24.23	19.19	2.00	8.00	20.88
Emission factor						10.59	2.00	7.41	13.08
AR 2002 – 2013	**Error % (biomass conversion)**					**Error % (C)**	**SE %**	**RMSE%**	**Error % (biomass conversion)**
Germany	**spruce**	**pine**	**beech**	**oak**	**softwood**		**all**		
above ground	11.23	15.62	18.80	12.10	50.00	11.10	2.00	6.08	12.81
below ground	34.60	26.30	49.00	50.00	24.23	17.48	2.00	5.63	18.47
Emission factor						9.69	2.00	5.93	11.53

Table 293: Uncertainties in emission factors for living biomass on deforestation areas, for various periods

DF 1987 – 2002	Error % (biomass conversion)						Error % (C)	SE %	RMSE%
Old German Länder	**spruce**	**pine**	**beech**	**oak**	**softwood**			**all**	
above ground	11.23	15.62	18.80	12.10	50.00	8.29	2.00	10.00	13.15
below ground	34.60	26.30	49.00	50.00	24.23	17.38	2.00	11.05	20.70
Emission factor						7.51	2.00	10.08	12.73
DF 2002 – 2013	**Error % (biomass conversion)**					**Error % (C)**	**SE %**	**RMSE%**	**Error % (biomass conversion)**
Germany	**spruce**	**pine**	**beech**	**oak**	**softwood**			**all**	
above ground	11.23	15.62	18.80	12.10	50.00	8.97	2.00	7.27	11.72
below ground	34.60	26.30	49.00	50.00	24.23	16.94	2.00	7.04	18.45
Emission factor						8.04	2.00	7.17	10.95

Table 294: Uncertainties in emission factors for dead wood on forest land remaining forest land, for various periods

FM 2002 – 2008	**Error % (biomass conversion)**													**Error % (C)**	**SE %**	**RMSE%**
Germany	**N1**	**N2**	**N3**	**N4**	**L1**	**L2**	**L3**	**L4**	**EI1**	**EI2**	**EI3**	**EI4**		**all**		
> 20 cm	12.30	19.82	25.12	17.87	8.87	30.62	23.95	46.25	8.92	31.54	23.71	53.23	8.36	2.00	30.80	31.98
10 to 20 cm	12.30	19.82	25.12	17.87	8.87	30.62	23.95	46.25	8.92	31.54	23.71	53.23	10.09	2.00	50.00	51.05
Emission factor																27.11
FM 2008 – 2013	**Error % (biomass conversion)**													**Error % (C)**	**SE %**	**RMSE%**
Germany	**N1**	**N2**	**N3**	**N4**	**L1**	**L2**	**L3**	**L4**	**EI1**	**EI2**	**EI3**	**EI4**		**all**		
> 20 cm	12.55	19.74	25.16	18.28	8.70	30.66	23.63	46.96	8.59	30.64	23.86	50.61	21.92	2.00	82.64	85.52
10 to 20 cm	12.26	19.77	25.14	17.82	8.54	30.60	23.57	46.41	8.54	30.66	23.67	47.47	13.23	2.00	30.91	33.69
Emission factor																54.52

where N = conifers (Nadelholz), L = deciduous trees (Laubholz), but not including oak, EI = oak (Eiche) and 1 – 4 = degree of decomposition

Table 295: Uncertainties in emission factors for dead wood on afforestation areas, 1990 to 2013

AR 1987 – 2013	**Error % (biomass conversion)**													**Error % (C)**	**SE %**	**RMSE%**
Germany	**N1**	**N2**	**N3**	**N4**	**L1**	**L2**	**L3**	**L4**	**EI1**	**EI2**	**EI3**	**EI4**		**all**		
> 20 cm	17.20	27.92	35.46	25.20	12.07	43.24	33.33	65.38	12.07	43.24	33.33	65.38	10.55	2.00	35.11	36.72
10 to 20 cm	17.20	27.92	35.46	25.20	12.07	43.24	33.33	65.38	12.07	43.24	33.33	65.38	13.05	2.00	28.37	31.30
Emission factor																24.84

where N = conifers (Nadelholz), L = deciduous trees (Laubholz), but not including oak, EI = oak (Eiche) and 1 – 4 = degree of decomposition

Table 296: Uncertainties in emission factors for dead wood on deforestation areas, for various periods

DF 2002 – 2008	**Error % (biomass conversion)**													**Error % (C)**	**SE %**	**RMSE%**
Germany	**N1**	**N2**	**N3**	**N4**	**L1**	**L2**	**L3**	**L4**	**EI1**	**EI2**	**EI3**	**EI4**		**all**		
> 20 cm	17.20	27.92	35.46	25.20	12.07								6.18	2.00	27.45	28.21
10 to 20 cm	17.20	27.92	35.46	25.20	12.07								13.05	2.00	50.00	51.10
Emission factor																24.88
DF 2008 – 2013	**Error % (biomass conversion)**													**Error % (C)**	**SE %**	**RMSE%**
Germany	**N1**	**N2**	**N3**	**N4**	**L1**	**L2**	**L3**	**L4**	**EI1**	**EI2**	**EI3**	**EI4**		**all**		
> 20 cm		27.92	35.46	25.20									6.18	2.00	27.45	28.21
10 to 20 cm	17.20	27.92	35.46	25.20	12.07	43.24	33.33	65.38					16.79	2.00	41.11	44.46
Emission factor																24.02

where N = conifers (Nadelholz), L = deciduous trees (Laubholz), but not including oak, EI = oak (Eiche) and 1 – 4 = degree of decomposition

6.4.3.3 Uncertainties in estimation pertaining to litter and mineral soils

6.4.3.3.1 Sampling error

In soil sampling, proper separation of litter and mineral soil can present a problem, since the transition between the two compartments cannot always be unambiguously identified. This problem becomes all the more important in light of the fact that carbon concentrations in litter differ considerably from those in mineral soil below the litter. In sampling, imprecise or improper separation of litter from mineral soil can thus have major impacts on the carbon stocks measured in a relevant horizon or depth layer.

6.4.3.3.2 Small-scale variability

Due to the high spatial variability in litter and mineral soil, and because carbon stocks maintain spatial continuity only over short distances, sampling of carbon stocks in such compartments is subject to a high degree of uncertainty. For litter in a beech forest, SCHÖNING et al. (2006) calculated stocks of 4.0 MgC ha^{-1}, with a variation coefficient of 38 %. In mineral soil (0 - 36 cm), they found carbon stocks of 64.0 Mg ha^{-1}, with variation coefficients between 30 % and 43 %. Similar values were recorded by LISKI (1995). He showed that different carbon stocks under a spruce site, and within a given horizon, were spatially independent as of a separation of 8 m.

6.4.3.3.3 Representativeness of points within strata

One problem in analysing samples in accordance with dominant soil units resulted from the different degrees to which classes were represented. Small classes lack statistical validity with respect to a major basic totality. Where no comparison between BZE I and BZE II data was possible, as a result of a lack of pertinent data, it was not possible to include the relevant forested dominant-soil-unit area in the calculation. In addition, it was not possible to have all dominant soil units represented, since some are found only on small areas of Germany's territory. All in all, as a result of these difficulties, 4.3 % of the forest area was not taken into account in this context.

6.4.3.3.4 Sampling error

In calculation of the sampling error with regard to stock changes in litter and mineral soil, paired and unpaired samples were differentiated, and stratification of mineral soils was taken into account. The variance of the mean stocks in stratum l, and of the unstratified total sample with n_l sample points, was calculated as follows:

Equation 35

$$v\langle \bar{Y}_l \rangle = \frac{1}{n_l(n_l-1)} \sum_{j=1}^{n_l} (Y_{lj} - \bar{Y}_l)^2$$

For paired samples, the variance of the mean stock changes in stratum l, between times t_1 and t_2, was calculated via:

Equation 36

$$v\langle \bar{G}_l \rangle = v\langle \bar{Y}_{lt_2} \rangle + v\langle \bar{Y}_{lt_1} \rangle - 2r_{y^2y^1}\sqrt{v\langle \bar{Y}_{lt_2} \rangle}\sqrt{v\langle \bar{Y}_{lt_1} \rangle}$$

where

$$r_{y^2y^1} = \frac{s_{y^2y^1}}{s_{y^2y^1}}$$

and

$$s_{y^2y^1} = \frac{1}{n_l(n_l-1)} \sum_{j=1}^{n_l} (Y_{ljt_2} - \overline{Y}_{lt_2})(Y_{ljt_1} - \overline{Y}_{lt_1})$$

For unpaired samples, the variance of stock changes was calculated via:

Equation 37

$$v\langle \overline{G_l} \rangle = v\langle \overline{Y}_{lt_2} \rangle + v\langle \overline{Y}_{lt_1} \rangle$$

The total variance, throughout all strata, was estimated, taking account of the area shares w_l / w for strata, as follows:

Equation 38

$$v\langle \overline{Y} \rangle \approx \sum_{l=1}^{L} \left(\frac{w_l}{w} \right)^2 v\left[\overline{Y}_l \right]$$

and with

$$v\langle \overline{G} \rangle \approx \sum_{l=1}^{L} \left(\frac{w_l}{w} \right)^2 v\left[\overline{G}_l \right]$$

The carbon-stock changes for litter were calculated on the basis of unpaired samples, with stratification. A sampling error of 0.02 MgC ha^{-1} a^{-1}, or 100 %, was obtained. In calculation of carbon-stock changes in mineral soil, the overall sample was divided into a paired sample set and an unpaired sample set. In addition, stratification, in keeping with the applicable dominant soil units and the two sample sub-sets, was carried out. Overall, the sampling error for mineral soils amounted to 0.037 MgC ha^{-1} a^{-1}, or 9 %.

6.4.3.3.5 Quantification of methodologically related uncertainties

Another source of uncertainty, in addition to sampling variance, consists of discrepancies, in individual measurements, that originate in measuring methods and processes. A group of several samples taken independently, at one and the same location, would exhibit fluctuations in both the C concentration and fine-earth fraction – throughout a range determined by the precision of the measuring equipment and methods being used. This fluctuation range in measurement of C concentrations was quantified on the basis of the results of ring analyses (BLUM & HEINBACH 2006, 2007). In the ring analyses for the Forest Soil Inventory II (BZE II), the repeatability standard deviation for a set of C measurements made by various laboratories was determined as the mean within-laboratory standard deviation (DIN ISO 5725 2) of the C measurements within the relevant laboratories, and the reference standard deviation was determined as the standard deviation of the mean values of the measurements. The reproducibility standard deviation was calculated from those standard deviations. The reproducibility standard deviation serves as a suitable estimate of the measurement uncertainty. The reproducibility standard deviations for mineral-soil measurements were as follows: 0.9 g kg^{-1} for (i.e. for measurements in) lime-free soils, 2.9 g kg^{-1} for calcareous soils and 20.2 g kg^{-1} for organic surface layers. With regard to the Forest Soil Inventory I (BZE I), the values provided by WOLFF & RIEK (1996) were used, including coefficients of variation ranging from 5 to 20 % for C measurements in mineral soils and from 5 to 10 % for C measurements in organic surface layers. The mean values of such coefficients were used in each case. No ring-analyses results were available as a basis for calculation of the uncertainties relative to fine-earth fractions. For this reason, all those BZE points were selected for which fine-earth-fraction results were available at both relevant inventory time points. The mean deviation between such measurement pairs was calculated. That mean deviation was 193 ± 35 Mg ha^{-1}. In keeping with the principle of conservative error estimation, it was assumed that the fine-earth fractions did not change between the two inventories, and that the mean deviation plus its spread serves as a measure of the uncertainty in measurement of fine-earth fractions. The uncertainty in the annual C-change range was expanded to include the uncertainties in the relevant individual measurements (Equation 39).

Equation 39:

$$s_{total}^2 = se^2 + \left(\frac{C_1}{(t_{II} - t_I)} MA_{FBV}\right)^2 + \left(\frac{FBV_1}{(t_{II} - t_1)} s_{C_1}\right)^2 + \left(\frac{FBV_{II}}{(t_{II} - t_1)} s_{C_{II}}\right)^2$$

The uncertainties in estimation of the annual rate of C change in mineral soils were as follows: for the sampling variance, 0.037 MgC ha^{-1} a^{-1}; for the laboratory analysis for C determination at the time of the BZE I, 0.058 MgC ha^{-1} a^{-1}; for such analysis at the time of the BZE II, 0.056 MgC ha^{-1} a^{-1}; and for determination of fine-earth fractions, 0.050 MgC ha^{-1} a^{-1}. These uncertainties yielded a total uncertainty of 0.11 MgC ha^{-1} a^{-1}. The total uncertainty in estimation of the annual C-change rate in the organic surface layer was 0.035 MgC ha^{-1} a^{-1}.

6.4.3.4 Time-series consistency

The following conditions are applied to the consistency of the time series:

- Throughout the entire time series, emissions must be calculated with the same method and the same or mutually consistent data sources.
- If any changes are made in a method, recalculations should be carried out with the new method throughout the entire time series.
- New data, such as data from repeat inventories, must be consistent with earlier data.
- If new data become available that lead to an improvement in the inventory, a recalculation should be carried out throughout the entire time series.
- If any errors are identified in estimates, they must be corrected, and the entire pertinent time series has to be recalculated.

These conditions for consistent time series have been systematically applied to all time series of the submission. Where "jumps" occur in time series, in certain years – for example, in the case of biomass (cf. Chapter 7.2.4.1) – then this is due to the periodicity of the available data within a consistent time series. This is because the same method, and the same data source, has been used for all years of such time series.

6.4.4 Category-specific QA / QC and verification (4.A)

With regard to quality control and quality assurance, we refer to Chapter 6.1.3.

The data sources used in preparation of this inventory fulfill the review criteria of the QSE manual for data sources (QSE-Handbuch für Datenquellen). Quality assurance for input data (ATKIS®, BÜK, official statistics, forest fire statistics; cf. Chapter 6.5.2.1) is the responsibility of the relevant data administrators (cf. the pertinent documentation in the inventory description).

In work carried out independently of the National Forest Inventory (BWI) calculations at the Thünen Institute of Forest Ecosystems, the C stocks and C-stocks changes for biomass were calculated with a programme developed under PostGreSQL. The results of the two sets of calculations agree.

Complete error analysis was carried out for the LULUCF sector, and an attempt was made to quantify all existing sources of error. That work included error calculations, relative to the forest sector, for biomass, dead wood, litter, mineral soils, organic soils and forest fires, and to the greenhouse gases CO_2, N_2O and CH_4. In Chapter 19.4.4, a total-error budget is presented that summarises the results of error analysis.

6.4.4.1 Biomass and dead wood

The estimates of carbon stocks in the biomass and dead-wood pools, at the various relevant times, and the estimates of carbon-stock changes are based on up-scaling that was carried out at the Thünen Institute for Forest Ecosystems (TI-WO), using data from the National Forest Inventories and from the Inventory Study 2008. With regard to the quality assurance developed for the National Forest Inventory, we call attention to the literature for the National Forest Inventory (BMELV 2005). In work carried out independently of the TI-WO's calculations, the C stocks and C-stocks changes for biomass were calculated with a programme developed under PostGreSQL. The results of the two sets of calculations agree.

6.4.4.2 Litter and mineral soils

In order to achieve a consistent standard of laboratory analysis in analysis of sampling carried out in the framework of the BZE surveys, ring analysis was initiated. To that end, all laboratories underwent a quality test carried out by the Gutachterausschuss Forstliche Analytik ("forestry analysis auditors' committee" (BLUM & HEINBACH 2006, 2007). To ensure the comparability of the applicable laboratory methods, only laboratories that participated successfully in the ring analysis were permitted to carry out relevant analysis. Ring analysis was also carried out at the European level, with German participation (COOLS et al. 2006).

To harmonise laboratory measurements and topographical surveys, rules for determining relevant parameters were defined, in the framework of the BZE II survey, for participating laboratories. This was done with a view to preventing any discrepancies resulting from use of different analysis equipment or methods (KÖNIG et al 2005, WELLBROCK et al. 2006). Previous ring analyses served as the basis for certifying laboratories for relevant analysis. A similar approach was taken with regard to field sampling. On the basis of various preliminary studies, suitable sampling methods were defined and specified, and described in a field-sampling manual (WELLBROCK et al. 2006).

6.4.4.3 Comparison with results of neighbouring countries

A comparison with the results of other countries can yield a basic context for the way in which the circumstances prevailing in Germany must be seen in comparison with those prevailing in neighbouring countries. In the "conversions to forest land" categories in particular, the methods and procedures used for handling transition time vary widely, and thus results in this area tend not to lend themselves directly to comparison.

A comparison of carbon-stock changes in living biomass (cf. Table 297) shows that, in the "conversions to forest land" categories, Germany has the highest sink performance. Only in the category of land converted from cropland to forest land were higher values reported – by the Netherlands. In the category of land conversions to forest land, the Czech Republic, Belgium and France rank in the middle of the range of reported sink performances, and Denmark is the only country to report lower carbon sources. In the category "Forest Land remaining Forest Land", on the other hand, Germany ranks in the middle part of the range. In this area, the Netherlands has the highest sink performance, while Austria has the smallest carbon sink.

In the dead organic matter pool (cf. Table 298), Germany is in the lower part of the overall range for conversions to forest land, with sink performance comparable to that of France. The highest sink performance in this category is seen in Switzerland, followed by Austria. In the area of conversions to forest land, Denmark is the only country with a negative balance. The UK has very low sink performance values. In the area of forest land remaining forest land, Germany, along with France, Poland and the Czech Republic, has reported a carbon source. Only the UK, the Netherlands, Austria and Belgium have a positive balance in this category, and the UK has reported the highest sink performance.

In the mineral soils category (cf. Table 299), Germany's sink performance in the category of forest land remaining forest land is surpassed only by that of Belgium. In this category, Austria is the only country to have registered carbon losses. In the "conversions to forest land" categories, Germany mostly has carbon sources. The only exception is the area of conversions to settlements and other land, in which Germany has moderate sink performance. The largest carbon sinks in this area are seen in Belgium, Austria and Switzerland.

Along with Germany, only Switzerland, Denmark, France, Poland and the UK report with regard to organic soils (cf. Table 300). Germany has a negative balance in all categories of this pool. In particular, in the category of forest land remaining forest land, Germany has reported the highest carbon losses. In the category of land converted to forest land, France has far and away the largest negative balance. The UK and Poland are the only countries with carbon sinks in all categories.

Table 297: Carbon-stock changes in living biomass, in various countries (Germany, for 2013; other countries, for 2012)

Country	Forest Land remaining Forest Land [MgC ha^{-1} a^{-1}]	Land converted to Forest Land [MgC ha^{-1} a^{-1}]	Cropland converted to Forest Land [MgC ha^{-1} a^{-1}]	Grassland converted to Forest Land [MgC ha^{-1} a^{-1}]	Wetlands converted to Forest Land [MgC ha^{-1} a^{-1}]	Settlements converted to Forest Land [MgC ha^{-1} a^{-1}]	Other Land converted to Forest Land [MgC ha^{-1} a^{-1}]
AUT	0.31	1.20	1.24	1.21	1.22	1.25	1.15
BEL	0.84	1.94	1.75	1.95	2.18	1.73	2.30
CHE	0.72	0.70	1.35	0.70	0.68	0.98	0.73
CZE	0.81	1.87	1.87	1.87	1.87	1.87	NA
DNK	1.78	-0.19	-0.29	-0.08	-0.07	NA	NA, NO
FRA	0.80	1.37	1.67	1.34	1.36	1.26	0.99

GBR	1.04	0.92	0.78	0.95	NO	0.83	0.91
GER	**1.03**	**3.25**	**3.40**	**3.03**	**3.64**	**3.55**	**3.64**
NLD	2.20	2.69	3.60	2.43	2.98	2.16	2.78
POL	1.11	1.05	1.05	1.05	NO	NO	NO

Source: UNFCCC 2014

Table 298: Carbon-stock changes in dead organic mass, in various countries (Germany, for 2013; other countries, for 2012)

Country	Forest Land remaining Forest Land [MgC ha-1 a-1]	Land converted to Forest Land [MgC ha-1 a-1]	Cropland converted to Forest Land [MgC ha-1 a-1]	Grassland converted to Forest Land [MgC ha-1 a-1]	Wetlands converted to Forest Land [MgC ha-1 a-1]	Settlements converted to Forest Land [MgC ha-1 a-1]	Other Land converted to Forest Land [MgC ha-1 a-1]
AUT	0.06	1.24	1.34	1.27	0.80	1.26	1.25
BEL	0.01	NO	NO	NO	NO	NO	NO
CHE	-0.23	1.51	0.13	1.55	1.23	0.50	1.30
CZE	NO	NA,NO	NO	NO	NO	NO	NA
DNK	0.51	-0.02	-0.02	-0.02	-0.02	NA	NA,NO
FRA	-0.04	0.31	0.52	0.25	0.51	0.35	0.47
GBR	0.22	0.03	0.03	0.04	NO	0.03	0.03
GER	**-0.03**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**
NLD	0.11	NE	NE	NE	NE	NE	NE
POL	-0.04	NO	NO	NO	NO	NO	NO

Source: UNFCCC 20143

Table 299: Carbon-stock changes in mineral soils, in various countries (Germany, for 2013; other countries, for 2012)

Country	Forest Land remaining Forest Land [MgC ha-1 a-1]	Land converted to Forest Land [MgC ha-1 a-1]	Cropland converted to Forest Land [MgC ha-1 a-1]	Grassland converted to Forest Land [MgC ha-1 a-1]	Wetlands converted to Forest Land [MgC ha-1 a-1]	Settlements converted to Forest Land [MgC ha-1 a-1]	Other Land converted to Forest Land [MgC ha-1 a-1]
AUT	-0.18	0.73	1.16	-0.71	NO	3.36	3.02
BEL	0.57	1.21	2.09	0.95	0.46	1.67	2.88
CHE	0.00	0.59	0.54	0.50	1.05	1.45	4.12
CZE	NO	0.14	0.47	0.02	NO	NO	NA
DNK	NA	0.15	0.14	0.16	-0.32	NA	NA
FRA	NO	0.24	1.07	-0.03	NO	1.54	NO
GBR	0.35	1.10	1.76	0.96	NO	1.46	1.17
GER	**0.41**	**-0.39**	**0.00**	**-0.83**	**-0.28**	**0.08**	**0.19**
NLD	NO	0.14	0.68	-0.26	0.06	0.38	2.20
POL	0.11	0.11	0.11	0.12	NO	NO	NO

Source: UNFCCC 2014

Table 300: Carbon-stock changes in organic soils, in various countries (Germany, for 2013; other countries, for 2012)

Country	Forest Land remaining Forest Land [MgC ha-1 a-1]	Land converted to Forest Land [MgC ha-1 a-1]	Cropland converted to Forest Land [MgC ha-1 a-1]	Grassland converted to Forest Land [MgC ha-1 a-1]	Wetlands converted to Forest Land [MgC ha-1 a-1]	Settlements converted to Forest Land [MgC ha-1 a-1]	Other Land converted to Forest Land [MgC ha-1 a-1]
AUT	NO	NO	NO	NO	NO	NO	NO
BEL	NO	NO	NO	NO	NO	NO	NO
CHE	-0.68	-0.32	-0.68	-0.68	-0.68	1.90	NO
CZE	NA,NO	NA,NO	NO	NO	NO	NO	NA
DNK	-0.34	-0.34	-0.34	-0.34	-0.34	NA	NA
FRA	NO	-10.48	NO	NO	-10.48	NO	NO
GBR	1.87	2.71	2.63	2.70	NO	2.92	2.76
GER	**-2.61**	**-2.61**	**-2.61**	**-2.61**	**-2.61**	**-2.61**	**-2.61**
NLD	NE	NE	NE	NE	NE	NE	NE
POL	0.68	0.68	0.68	0.68	NO	NO	NO

Source: UNFCCC 2014

6.4.5 Category-specific recalculations (4.A)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

Because the IPCC 2006 Guidelines (IPCC 2006) have been implemented in this year's submission, a complete recalculation of the inventory was carried out, on the basis of those Guidelines. It covered all category-specific time series for the entire reporting period, 1990 – 2013.

6.4.6 Category-specific planned improvements (4.A)

No further improvements, in addition to those previously announced, are planned. Information about the implementation status of planned improvements in the LULUCF sector is presented in Chapter 6.1.4.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

6.5 Cropland (4.B)

6.5.1 Category description (4.B)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T/2	**4.B Cropland**		**CO2**	**15.474,5**	**(1,27%)**	**13.671,4**	**(1,46%)**	**-11,7%**
-/-	4.B Cropland		N2O	268,1	(0,02%)	309,0	(0,03%)	15,2%
-/-	4.B Cropland		CH4	263,1	(0,02%)	231,1	(0,02%)	-12,2%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	RS/NS	CS
N_2O	Tier 2	RS/NS	CS
CH_4	Tier 2	RS/NS	CS

The category *Cropland* (4.B) is a key category for CO_2 emissions in terms of emissions level and trend, and in terms of Tier 2 analysis.

Reporting in the *Cropland* category covers emissions / removals of CO_2 from/in mineral and organic soils, and from/in above-ground and below-ground biomass. It also includes direct and indirect nitrous oxide emissions from humus losses from mineral soils, following land-use changes leading to cropland, and it covers methane emissions from organic soils. In keeping with the IPCC Guidelines (IPCC 2006), direct and indirect nitrous oxide emissions from fertiliser application (artificial fertiliser, manure, sewage sludge, etc.), crop residues and drainage of organic soils under cultivation are reported under Agriculture (CRF 3.D). For this reason, in the Cropland chapter, those categories are marked as "IE". Burning of fields and crop residues is prohibited by law in Germany (Federal Law Gazette (BGBl) 2004) and thus is not reported (NO).

Emissions from cropland are listed, broken down by categories, in Table 287. The relevant total emissions in 2013 in Germany amounted to 14,280.9 Gg CO_2 equivalents. The main emissions sources are soils, especially organic soils under cultivation (75.6 %). Mineral soils contributed 24 % of the total emissions. Most emissions from mineral soils resulted from tillage of grassland (such emissions accounted for 88.4 % of the total for mineral soils). The cropland sector registers low levels of anthropogenically related releases of CO_2 from biomass (0.1 %) and from dead organic matter (0.4 %).

The predominating greenhouse gas in the cropland sector is CO_2, accounting for 13,671.4 Gg CO_2 equivalents (95.7 %). The reported nitrous oxide emissions (totalling 2.7 %; consisting of direct emissions (308.97 Gg CO_2-eq. (4.(III)) and indirect emissions (69.5 Gg CO_2-eq. (4.(IV)) from decomposition of organic soil substance as a result of land-use changes leading to cropland) and methane emissions (1.6 %; from use of organic soils) are low by comparison.

Table 301: CO_2, N_2O and CH_4 emissions [Gg CO_2-eq.] from Germany's cropland, 2013. The table includes both the relevant sums and the upper and lower bounds of the 95 % confidence interval.

Category	**GHG**	**Cropland, emissions, 2013 [Gg CO_2-eq.]**			**[%]**	
		Emission	**2.5 perc.**	**97.5 perc.**	**2.5 perc.**	**97.5 perc.**
$Cropland_{total}$		14,280.9	10,535.4	16,429.1	26.2	15.0
Mineral soils	CO_2	3,050.2	2,162.1	4,531.3	29.1	48.6
	N_2O_{direct}	**309.0**	277.5	646.6	89.8	209.3
	$N_2O_{indirect}$	**69.5**	0	202.6	100	291.5
Organic soil	CO_2	10,558.4	6,801.0	11,994.9	35.6	13.6
	N_2O	IE	IE	IE	IE	IE
	CH_4	231.1	110.9	652.5	52.0	182.4
Biomass	CO_2	9.6	8.4	10.9	12.3	13.4
Litter / dead wood	CO_2	53.1	50.0	58.9	5.9	10.8

Figure 63 and Figure 64 show the trends in emissions from cropland. The total emissions in 2013 were -1,785.2 Gg CO_2 ≙ -11.1 % lower than in the reference year 1990. Nonetheless, emissions from cropland have increased again slightly since 2005. The main reason for this general trend is that emissions from organic soils in the "remaining" category have decreased as a result of reductions in the relevant area (-8.1 %). In addition, the decrease in the deforested area, amounting to 43 %, resulted in 53 % lower emissions from deforestation in 2013. A similar statement can be made for land-use changes from Settlements and Wetlands to Cropland; in these categories as well, the applicable areas – and, thus, the relevant emissions – have decreased with respect to the corresponding levels in 1990 (Settlements: -31 %; Wetlands: -58 %), although the decreases have taken place on a considerably lower level of magnitude.

The trend reversal since 2005 is due primarily to emissions resulting from land-use change from Grassland (in the strict sense) to Cropland. Since 2005, the tilled acreage on Germany's organic and mineral soils has increased by 282,823 ha ≙ 39 %, and that has increased Cropland emissions by 1,281.2 Gg CO_2 ≙ 33.3 %.

The key categories that are responsible for the changes in the time series include, on the one hand, CO_2 emissions from organic and mineral soils and, on the other, a decrease in emissions from biomass and dead organic matter as a result of a sharp decrease in deforestation.

The shapes of the time-series plots – especially the noticeable changes they show – are due primarily to the periodicity in surveying of the relevant area data. Land-use changes were determined on the basis of spatially explicit land-use data – data records from the years 1990, 2000, 2005 2008, 2012 and 2013 (cf. Chapter 6.4). Land-use changes that occurred between those years were determined via linear interpolation, and thus the annual conversion areas did not change between the times at which spatially explicit data were evaluated. The main reason for the marked emissions decrease between 2000 and 2001 is a considerable decrease in deforestation.

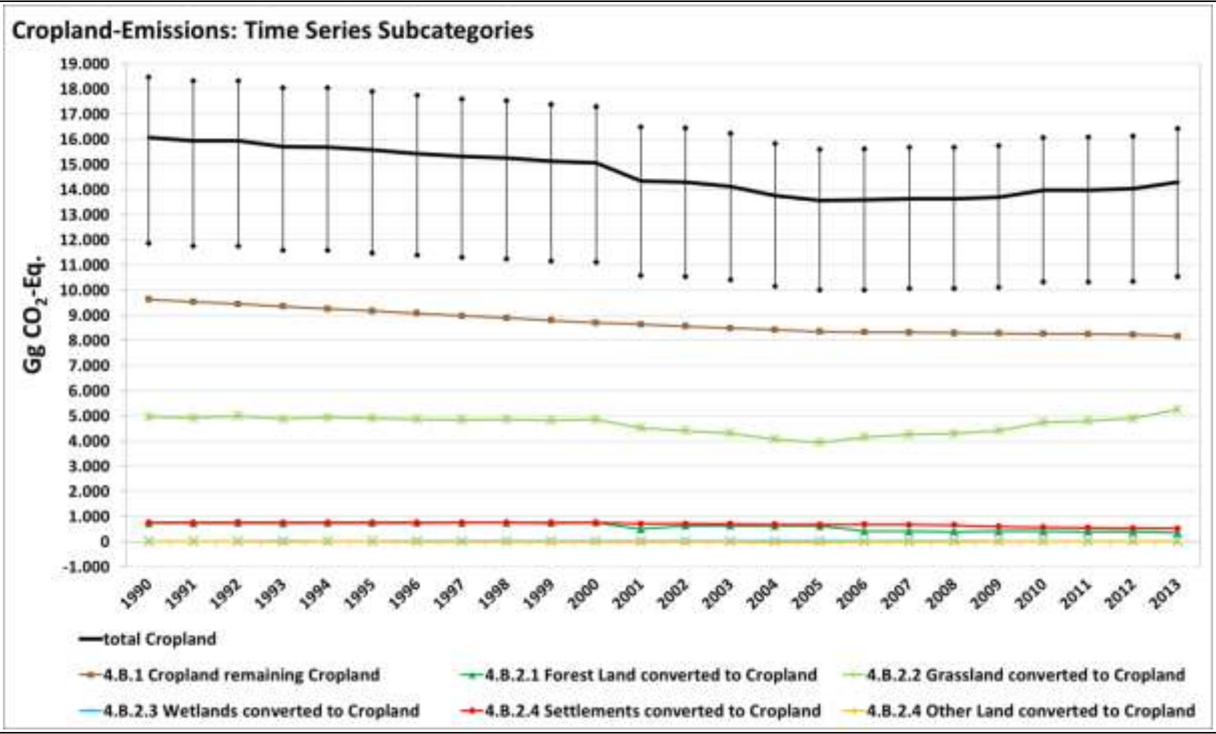

Figure 63: Greenhouse-gas emissions from cropland **(total of CO_2, CH_4 and N_2O)** [Gg CO_2-Eq.] as a result of land use and land-use changes, 1990 – 2013, by sub-categories (with uncertainties shown only for the total sum)

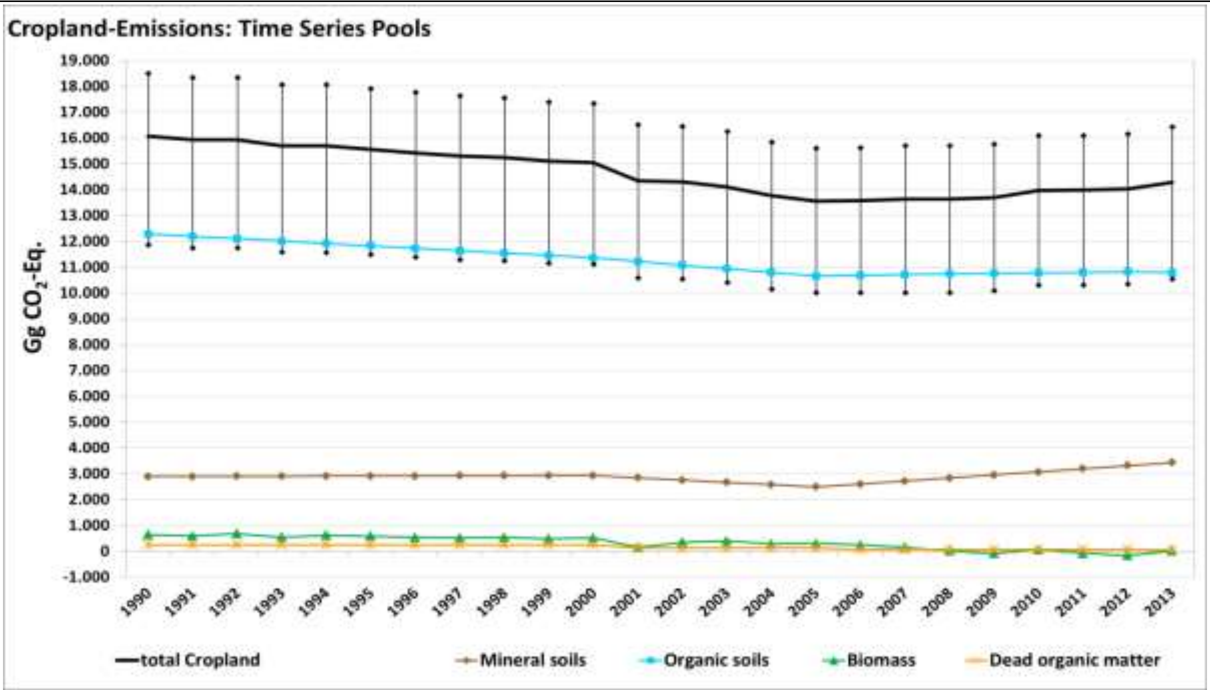

Figure 64: Greenhouse-gas emissions from cropland (total of CO_2, CH_4 and N_2O) [Gg CO_2-Eq.] as a result of land use and land-use changes, 1990 – 2013, by pools (with uncertainties shown only for the total sum)

6.5.2 Methodological issues (4.B)

6.5.2.1 Biomass

No carbon-stock changes are listed for the "remaining as" Cropland category, since it is assumed carbon flows and biomass are in balance in that category; under the gain-loss method, therefore ΔC = 0 (Equation 2.7 in the 2006 IPCC Guidelines). Consequently, "NO" (not occurring) has been entered in the CRF Table 4.B.1 under the pools "living biomass" and "dead organic matter". This assumption is made in light of the representative "equilibrium carbon stocks" determined for Germany's permanent crops. In keeping with the IPCC guidelines, annual crops are not taken into account in the "Cropland remaining Cropland" category (IPCC 2006). The mean carbon stocks in fruit trees are calculated on the basis of a complete tree count with differentiation by tree type and age (< 1 - > 25 years). With the help of Pöpken (2011), it was possible to determine representative equilibrium carbon stocks for all cultivated woody plants, since the approach included summation over all age classes, tree / shrub types and plantation structures and combinations – Chapter 19.4.3.1. As a rule, annual growth increments in cultivated woody plants are completely pruned away. Since the rotation periods for woody plants tend to be relatively short (about 10 – 15 years for fruit trees), such plantations tend to rejuvenate frequently. Such rejuvenation occurs from the pool used to derive the pertinent emission factors, however. The processes of planting, growth, pruning, harvest and rejuvenation reach a state of dynamic equilibrium. In the case of land-use changes leading to cropland, the C stocks accruing through planting of wood biomass are thus credited completely in the year of the land-use change. The carbon-stock changes resulting from land-use changes are determined, and reported, for both annual and perennial biomass.

6.5.2.1.1 Carbon stocks in the biomass of permanent crops (perennial arable crops)

The carbon stocks in the biomass of permanent crops have been derived using the methods set forth in Chapter 19.4.3.1. That chapter also presents the applicable data and individual factors. Table 302 shows the results, namely the carbon stocks for land with permanent crops.

Table 302: Area-weighted mixed value for carbon stocks [Mg C ha^{-1} ± half of the 95 % confidence interval] for permanent crops, 2013

Permanent crops	Carbon stocks [Mg C ha^{-1}]		
	Bio_{total}	$Bio_{above\text{-}ground}$	$Bio_{below\text{-}ground}$
Cropland: Permanent crops	11.54 ± 1.57	8.10 ± 0.51	3.44 ± 1.37

6.5.2.1.2 Carbon stocks in the biomass of annual arable crops

In connection with land-use changes, area-weighted mean figures are used for the above-ground and below-ground biomass of annual arable and horticultural crops, and of permanent crops. This approach is in keeping with IPCC 2006. The carbon stocks in the above-ground and below-ground biomass of annual arable crops are calculated annually on the basis of the Federal Statistical Office's harvest statistics. Mean carbon stocks, weighted by area and harvest, and referenced to the area of annual arable crops and horticultural crops, are then calculated from those stocks.

The basis for determination of the mean carbon stocks for field crops consists of the data on harvests and area under cultivation for a total of 65 field crops. They are as follows:

- Winter wheat, spring wheat, rye, triticale, maslin, winter barley, spring barley, oats, mixed grains other than maslin, grain maize
- Field peas, broad beans
- Potatoes, sugar beets, fodder beets
- Winter oilseed rape
- Clover, alfalfa, grass, silage maize
- Cauliflower, broccoli, Chinese cabbage, kale, kohlrabi, Brussels sprouts, red cabbage, white cabbage, savoy, oak-leaf lettuce, iceberg lettuce, endive, lamb's lettuce, head lettuce, lollo lettuce, radicchio, romana lettuce, arrugula, other lettuce types, spinach, rhubarg, asparagus, celery, fennel, celeriac, horseradish, carrots, radishes, (larger) radishes, red beets, pickling cucumbers, slicing cucumbers, edible pumpkins, zucchini, sweet corn, bush beans, broad beans, runner beans, split peas, peas, bunching onions, onions, parsley, leeks, chives

The dry biomass of individual plant parts is derived from harvest data, pursuant to HAENEL et al. (2014), using relevant ratios and water-content data (obtained from various sources). The data and methods used are consistent with those used to calculate nitrogen in crop residues (CRF 4.D).

For calculation of biomass carbon stocks, an average carbon content of 45 % by weight was assumed – and used instead of the IPCC default value (50 % by weight) – since OSOWSKI et al. (2004) give carbon contents of 44 – 48 % by weight for plants in central Europe and since PÖPKEN (2011), in her studies of cultivated trees (carried out for the German inventory), also found average values of 45 to 46 % by weight. The relevant results for annual arable and horticultural crops are shown in Table 303.

Table 303: Area-based carbon stocks [Mg C ha^{-1}] (± half of the 95 % confidence interval) in Cropland with annual vegetation

Year	Carbon stocks [Mg C ha^{-1}] Cropland$_{annual}$		
	Bio$_{total}$	**Bio$_{above-ground}$**	**Bio$_{below-ground}$**
1990	6.03 ± 0.57	4.84 ± 0.45	1.19 ± 0.34
1991	6.27 ± 0.60	5.07 ± 0.47	1.21 ± 0.34
1992	5.81 ± 0.55	4.71 ± 0.44	1.10 ± 0.31
1993	6.57 ± 0.63	5.32 ± 0.49	1.25 ± 0.35
1994	6.15 ± 0.59	4.97 ± 0.46	1.18 ± 0.33
1995	6.35 ± 0.60	5.14 ± 0.48	1.21 ± 0.34
1996	6.60 ± 0.63	5.35 ± 0.50	1.24 ± 0.35
1997	6.73 ± 0.64	5.46 ± 0.51	1.27 ± 0.36
1998	6.62 ± 0.63	5.37 ± 0.50	1.25 ± 0.35
1999	6.84 ± 0.65	5.56 ± 0.52	1.29 ± 0.36
2000	6.70 ± 0.64	5.45 ± 0.51	1.25 ± 0.35
2001	6.99 ± 0.67	5.67 ± 0.53	1.31 ± 0.37
2002	6.45 ± 0.61	5.25 ± 0.49	1.21 ± 0.34
2003	5.82 ± 0.55	4.75 ± 0.44	1.07 ± 0.30
2004	7.32 ± 0.70	5.95 ± 0.55	1.36 ± 0.38
2005	6.96 ± 0.66	5.64 ± 0.52	1.32 ± 0.37
2006	6.56 ± 0.62	5.30 ± 0.49	1.26 ± 0.36
2007	6.84 ± 0.65	5.54 ± 0.51	1.31 ± 0.37
2008	7.33 ± 0.70	5.92 ± 0.55	1.40 ± 0.40
2009	7.51 ± 0.71	6.08 ± 0.56	1.43 ± 0.40
2010	7.01 ± 0.67	5.67 ± 0.53	1.35 ± 0.38
2011	7.48 ± 0.71	6.05 ± 0.56	1.43 ± 0.40
2012	7.79 ± 0.74	6.30 ± 0.59	1.50 ± 0.42
2013	7.46 ± 0.71	6.02 ± 0.56	1.44 ± 0.41

6.5.2.1.3 Total carbon stocks in cropland biomass

The total biomass in cropland is calculated as area-weighted annual carbon stocks, pursuant to Equation 40.

Equation 40:

$$C_{crop} = \frac{(C_{perm.crop} * A_{perm.crop} + C_{annual} * A_{annual})}{(A_{perm.\ crop} + A_{annual})}$$

C_{crop}: Area-weighted mixed value for carbon stocks in the biomass of annual and permanent crops on cropland [Mg C ha^{-1}]
$C\_{perm.\ crop}$: Average carbon stocks in the biomass of permanent crops (perennial arable crops) [Mg C ha^{-1}]
C_{annual}: Average carbon stocks in the biomass of annual arable crops [Mg C ha^{-1}]
$A\_{perm\ crop}$: Cropland area with permanent crops [ha]
A_{annual}: Cropland area with annual crops [ha]

The values shown in Table 304 are used as a basis for all calculations relative to biomass in connection with land-use changes in the area of cropland and horticultural land.

Table 304: Area-weighted mixed value for carbon stocks [Mg C ha^{-1} ± half of the 95 % confidence interval] in cropland biomass in Germany

Year	Carbon stocks [Mg C ha^{-1}] Cropland$_{area-weighted}$		
	Bio$_{total}$	Bio$_{above-ground}$	Bio$_{below-ground}$
1990	6.11 ± 0.56	4.88 ± 0.44	1.23 ± 0.33
1991	6.35 ± 0.59	5.11 ± 0.46	1.25 ± 0.34
1992	5.90 ± 0.55	4.76 ± 0.43	1.14 ± 0.31
1993	6.64 ± 0.61	5.35 ± 0.49	1.29 ± 0.35
1994	6.23 ± 0.58	5.01 ± 0.45	1.22 ± 0.33
1995	6.43 ± 0.59	5.18 ± 0.47	1.25 ± 0.34
1996	6.67 ± 0.62	5.39 ± 0.49	1.28 ± 0.35
1997	6.80 ± 0.63	5.49 ± 0.50	1.31 ± 0.35
1998	6.69 ± 0.62	5.40 ± 0.49	1.29 ± 0.35
1999	6.91 ± 0.64	5.59 ± 0.51	1.32 ± 0.36
2000	6.77 ± 0.63	5.48 ± 0.50	1.29 ± 0.35
2001	7.05 ± 0.65	5.70 ± 0.52	1.35 ± 0.36
2002	6.52 ± 0.60	5.28 ± 0.48	1.24 ± 0.34
2003	5.90 ± 0.55	4.79 ± 0.43	1.11 ± 0.30
2004	7.37 ± 0.68	5.97 ± 0.54	1.40 ± 0.38
2005	7.02 ± 0.65	5.67 ± 0.51	1.35 ± 0.37
2006	6.62 ± 0.61	5.33 ± 0.48	1.29 ± 0.35
2007	6.90 ± 0.64	5.57 ± 0.50	1.34 ± 0.36
2008	7.38 ± 0.68	5.95 ± 0.54	1.43 ± 0.39
2009	7.57 ± 0.70	6.11 ± 0.55	1.46 ± 0.40
2010	7.08 ± 0.66	5.70 ± 0.52	1.38 ± 0.37
2011	7.55 ± 0.70	6.08 ± 0.55	1.47 ± 0.40
2012	7.84 ± 0.73	6.32 ± 0.57	1.52 ± 0.41
2013	7.51 ± 0.69	6.05 ± 0.55	1.46 ± 0.40

6.5.2.2 Mineral soils

No change in carbon stocks in mineral soils is listed for areas remaining as cropland. The constancy of carbon stocks since the early 1990s is evidenced by the results obtained on 140 regional long-term-trial areas (HÖPER und SCHÄFER 2012, FORTMANN et al. 2012 and BAYERISCHE LANDESANSTALT FÜR LANDWIRTSCHAFT 2007). Recent meta-studies (BAKER et al. 2007; LUO et al. 2010) have also shown, for soil depths > 60 cm, that the type of soil cultivation used has no influence on the total carbon stocks in mineral soils. In agricultural soil use, the soil-cultivation and soil-management methods used thus do not change rapidly over large areas. In CRF Table 4.B.1, "NO" (not occurring) has thus been entered in the space "carbon-stock change in mineral soils" in the "remaining" category.

The manner in which CO_2 emissions resulting from conversions leading to cropland are calculated is described in Chapter 6.1.2.1.1, while the pertinent calculations for N_2O emissions are described in Chapter 6.1.2.1.2. The emission factors for carbon are shown in Table 258 and Table 259 (Chapter 6.1.2.1.1), while the emission factor for direct nitrous oxide emissions is shown in Table 260 and the factor for indirect N_2O emissions is shown in Table 261(Chapter 6.1.2.1.2). The manner in which the emission factors have been derived is described in Chapter 19.4.2, while the pertinent uncertainties are listed in Table 290 (Chapter 6.6.3). The results for emissions from mineral soils are presented in the following areas in the Common Reporting Framework:

- CO_2 emissions, in Tables 4.B.2.1 - 4.B.2.5
- Direct N_2O emissions, in Table 4.III.2.1 - 4.III.2.5
- Indirect N_2O emissions, in Table 4.IV.2

6.5.2.3 Organic soils

The procedure for calculating CO_2, N_2O and CH_4 emissions from organic soils that result from land use and land-use changes, and the procedure for deriving the pertinent emission factors, is described in Chapter 6.1.2.1. The annual emissions following land-use changes are calculated in a manner similar to that used for emissions from cropland remaining cropland. The latter are listed in CRF Table 4.B.1, while emissions resulting from land-use changes are listed in Tables 4.B.2.1 - 4.B.2.5 ausgewiesen.

N_2O emissions from organic soils are reported as part of the "Agriculture" sector, under Chapter 3.D.a.6 "Cultivation of Histosols". To prevent double-counting, N_2O emissions from organic soils that result from conversions to cropland are listed in the LULUCF table 4.II.B with the notation key "IE".

Methane emissions from organic soils, and from drainage ditches, are included in the figures in CRF Table 4.II.B.

6.5.3 Uncertainties and time-series consistency (4.B)

The uncertainties for the emission factors and the activity data were determined in accordance with the 2006 IPCC Guidelines (IPCC 2006). Additional relevant information is provided in Chapter 19.4.4. Table 305 and 291 show the uncertainties in the emission factors for the cropland sector, broken down by pools and sub-categories.

Table 305 highlights the fact that distributions based on natural processes are often not symmetric and thus often have to be described with left-skewed and right-skewed (with steep sloping on the one side or other) distributions. Only the emission factors for biomass show standard normal distributions / distributions that are approximately normal. Furthermore, the uncertainties seen in this area are the smallest of all relevant uncertainties. With the exception of the emission factor for CO_2 from organic soils, which exhibits a right-skewed distribution, the other EF for soils tend to show log-normal distributions. The emission factors for N_2O emissions from mineral soils show the largest uncertainties. This is due primarily to use of the IPCC default factors.

In calculation of Gaussian error propagation, uncertainties > 100 % were calculated for the lower bound of the 95 % confidence interval for the uncertainties for emission factors for indirect N_2O emissions. While this calculation method conforms to the applicable rules, mathematical rigour dictates that it not be used in the present context. Pursuant to the assumptions on which the method for calculating indirect N_2O emissions from mineral soils is based, no negative emissions can occur. For this reason, the uncertainty for the lower bound has been set to 100 %.

The large uncertainty seen in the emission factors for methane and nitrous oxide from organic soils is due to those factors' extremely large variability in field measurements, as well as to the fact that negative emissions are possible for methane (cf. Chapter 6.1.2.2.2).

The uncertainties for the activity data, the areas, are shown in Table 426 in Chapter 19.4.4. Those uncertainties have a normal distribution, and half of the 95 % confidence interval, in the cropland sector, falls within the range 1 – 102 %. For system-related reasons, the sampling error with the grid-point approach depends on the sample size, and thus on the relevant sub-category's share of the total area (cf. Chapter 6.3). Consequently, in the cropland sector major uncertainties are seen only for those sector sub-categories whose share of the total cropland area is < 0.1 %. Area-weighted derivation of a total uncertainty for the area data in the cropland category yields an uncertainty of 1.05 % [half of the 95% confidence interval].

Table 426 in Chapter 19.4.4 shows that, in the cropland sector, and in terms of total emissions, emissions from organic soils have an especially significant share of national LULUCF emissions. Emissions from mineral soils and, especially, those occurring in connection with biomass, have only a small share.

Table 305: Uncertainties of emission factors [2.5 and 97.5 percentile, in % of location scale] used for calculation of GHG emissions from Germany's croplands in 2013, broken down by pools and sub-categories

Cropland Land use before Mineral soils, CO_2-C[99]	**Land use after**	**Emission factor [$Mg\ C\ ha^{-1}\ a^{-1}$]**	**Boundaries upper [%]**	**lower [%]**
Forest land	Cropland	-0.025	16.9	25.0
Grassland (in a strict sense)	Cropland	-0.870	29.6	49.1
Woody grassland	Cropland	-0.658	27.9	51.1
Terr. wetlands	Cropland	-0.699	28.4	36.8
Waters	Cropland	0	33.0	50.5
Settlements	Cropland	0.068	27.9	49.2
Other land	Cropland	0.221	27.4	51.8
Mineral soils, N_2O_{direct}[100]		[$kg\ N_2O\text{-}N\ ha^{-1}\ a^{-1}$]	[$kg\ N_2O\text{-}N\ ha^{-1}\ a^{-1}$]	[%]
Forest land	Cropland	0.029	72.1	201.6
Grassland (in a strict sense)	Cropland	1.078	91.0	211.9
Woody grassland	Cropland	0.845	90.4	212.4
Terr. wetlands	Cropland	0.711	90.6	209.4
Mineral soils, $N_2O_{indirect}$[101]		**[$kg\ N_2O\text{-}N\ ha^{-1}\ a^{-1}$]**	**[$kg\ N_2O\text{-}N\ ha^{-1}\ a^{-1}$]**	**[%]**
Forest land	Cropland	0.007	100	287.8
Grassland (in a strict sense)	Cropland	0.243	100	295.2
Woody grassland	Cropland	0.190	100	295.5
Terr. wetlands	Cropland	0.160	100	293.4
Organic soil[102]		**[$Mg\ C\ ha^{-1}\ a^{-1}$]**	**[$Mg\ C\ ha^{-1}\ a^{-1}$]**	**[%]**
Cropland	CO_2	29.70	45.7	17.4
Cropland	N_2O	5.01	85.5	286.5
Cropland	CH_4	0.65	66.7	233.9

[99] Calculation covers a 20-year period; stock change: positive ≙ sink; negative ≙ source

[100] Calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink

[101] Calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink

[102] Annual calculation; emission: positive ≙ source; negative ≙ sink

Cropland Land use before	Land use after	Emission factor	Boundaries upper	lower
Biomass103		**[Mg C ha^{-1} a^{-1}]**	**[Mg C ha^{-1} a^{-1}]**	**[%]**
Forest land	Cropland	-47.97	19.9	19.9
Grassland (in a strict sense)	Cropland	0.84	12.9	12.9
Woody grassland	Cropland	-36.48	46.2	47.1
Terr. wetlands	Cropland	-11.32	30.6	31.1
Waters	Cropland	7.52	9.3	9.3
Settlements	Cropland	-4.94	29.6	30.1
Other land	Cropland	7.52	9.3	9.3
Dead organic matter104		**[Mg C ha^{-1} a^{-1}]**	**[Mg C ha^{-1} a^{-1}]**	**[%]**
Forest land	Cropland	-20.70	5.9	5.9

The calculations are spatially and chronologically consistent and complete for the entire report period, 1990 – 2013.

6.5.4 Category-specific quality assurance / control and verification (4.B)

With regard to quality control and quality assurance, we refer to Chapter 6.1.3.

The data sources used in preparation of this inventory fulfill the review criteria of the QSE manual for data sources (QSE-Handbuch für Datenquellen). Quality assurance for input data (ATKIS®, BÜK, official statistics; cf. Chapter 6.3) is the responsibility of the relevant data administrators (cf. the pertinent documentation in the inventory description).

The emissions-calculation results as presented in the present report cannot be compared with other relevant data sources for Germany, since no such other data sources exist that meet applicable requirements, i.e. provide complete coverage, are comprehensive and are independent of the methods and data sources described in the present report.

- Table 291 presents an intra-European comparison of implied emission factors (IEF), for various pools. Only comparative values are included that have already been reported in past years. No comparative values are available for those values for which reporting obligations began only with this year's introduction of the 2006 IPCC Guidelines (for example, methane emissions from organic soils, indirect N_2O emissions). The comparison shows – especially when the large pertinent uncertainties and broad scattering of reported values are taken into account (cf. Chapter 6.5.3) – that the country-specific values for Germany exhibit no conspicuous differences from those of Germany's neighbours in terms of order of magnitude. For methodological reason, two values have changed with respect to the previous year: The previous IEF for CO_2 emissions from organic soils, -11 Mg CO_2-C ha^{-1}, has been replaced by a new factor, determined via a nationwide research project, of -8.1 Mg CO_2-C ha^{-1}. The new value is of a similar order of magnitude, and it is comparable to those of neighbouring countries. On the other hand, it is now at the lower boundary of the relevant range, especially when the 95% confidence interval is taken into account (-4.4 Mg to -9.7 Mg CO_2-C ha^{-1}).
- As a result of the change in the IPCC default value, the IEF for direct N_2O emissions resulting from losses of organic soil substance has changed from 0.0125 to 0.01 kg N_2O-N (kg N)$^{-1}$.

In the German inventory, carbon-stock changes in mineral soils, biomass and dead organic matter (only for conversions from forest land to cropland) are taken into account only in

[103] Calculation only for first year of land-use change, stock change: positive ≙ sink; negative ≙ source

[104] Calculation only for first year of land-use change, stock change: positive ≙ sink; negative ≙ source

connection with land-use changes leading to cropland; they are not taken into account in connection with cropland remaining cropland. The C emissions from mineral soils and biomass, as shown in the German calculations, are lower than the corresponding European average, but would fall within the middle range of neighbouring countries' implied emission factors. The same applies to C emissions from dead organic matter.

Table 306: Comparison of implied emission factors (IEF) for different cropland-sector pools in Europe, for the year 2012 (exception: Germany, NIR 2015: the 2013 figure is used, for comparison)

Implied emission factors (IEF), NIR 2014	Cropland remaining cropland	Conversions to cropland			
	Organic soils	Mineral soils	Biomass	Dead org. matter	Nitrous oxide
		Mg C ha^{-1}			kg N_2O-N ha^{-1}
Austria	NO	**-0.99**	**0.06**	**-0.04**	**1.00**
Belgium	-10.00	**-1.58**	**-0.11**	**-0.01**	**1.48**
Denmark	-10.62	**0.01**	**0.28**	**-0.04**	**0.03**
France	NO	**-1.18**	**-0.15**	**-0.02**	**1.13**
UK	-1.90	**-1.13**	**0.00**	**0.00**	**0.22**
Netherlands	IE	**-0.65**	**-0.41**	**-0.05**	**0.52**
Poland	-1.00	**-1.02**	**NO**	**NO**	**14.88**
Czech Republic	NO	**-0.34**	**-0.14**	**0.00**	**0.39**
Switzerland	-9.52	**-0.18**	**-0.04**	**0.00**	**0.50**
Germany, NIR 2014	-11.00	-0.79	-0.0006	-0.01	0.77
Germany, NIR 2015	**-8.10**	**-0.80**	**-0.0023**	**-0.01**	**0.33**[105] **(0.07)**[106]

Positive: C sink or N_2O source; negative: C source or N_2O sink

6.5.5 *Category-specific recalculations (4.B)*

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

Because the 2006 IPCC Guidelines (IPCC 2006) have been implemented in this year's submission, a complete recalculation of the inventory was carried out, on the basis of those Guidelines. It covered all category-specific time series for the entire reporting period, 1990 – 2013.

6.5.6 *Category-specific planned improvements (4.B)*

No further improvements, in addition to those previously announced, are planned. Information about the implementation status of planned improvements in the LULUCF sector is presented in Chapter 6.1.4.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

[105] Direct emissions
[106] Indirect emissions

6.6 Grassland (4.C)

6.6.1 Category description (4.C)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T/2	**4.C Grassland**	**0**	**CO2**	**20.882,1**	**(1,71%)**	**22.237,6**	**(2,38%)**	**6,5%**
-/-/2	**4.C Grassland**	**0**	**CH4**	**489,5**	**(0,04%)**	**517,6**	**(0,06%)**	**5,7%**
-/-	4.C Grassland	0	N2O	22,5	(0,00%)	20,0	(0,00%)	-11,0%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	RS/NS	CS
N_2O	Tier 2	RS/NS	CS
CH_4	Tier 2	RS/NS	CS

The category *Grassland* (4.C) is a key source of CO_2 emissions in terms of emissions level and trend and of Tier 2 analysis. For CH4, it is a key source of Tier 2 analysis only.

In 2013, the net anthropogenic GHG emissions from grassland amounted to 22,776.1 Gg CO_2 equivalents (95% confidence interval: 13726.7 - 27553.5 Gg CO_2 equivalents]. Drainage of organic grassland soils resulted in emissions of 25024.5 Gg CO_2, 517.6 Gg CO_2-eq. of methane, and 15.6 Gg CO_2-eq. of nitrous oxide. Losses via decomposition of dead wood and litter from deforestation amounted to 165.5 ± 9.8 Gg CO_2. In the grassland sector, both biomass (-517.3 Gg CO_2) and mineral soils (-1896.5 Gg CO_2) function as carbon sinks.

These emissions consist of the sum of the emissions from the sub-categories grassland (in a strict sense) and woody grassland, whose GHG emissions differ considerably, both quantitatively and qualitatively. As Table 287 and Figure 65 and Figure 66 show, Grassland (in the strict sense) is clearly a CO_2 source. Its absolute emissions magnitude of 23,665.6 Gg CO_2-eq. is dominated by emissions from organic soils (104.8 %), and the fractional role of CO_2 (97.9 %) greatly exceeds that of methane (2.1 %). While biomass and dead organic matter also function as small CO_2 sources (2.3 %), mineral soils under grassland (in the strict sense) are a lasting carbon sink, accounting for 7.1 % of the net sum for this sub-category.

Table 307: CO_2, N_2O and CH_4 emissions [Gg CO_2-eq.] from Germany's grassland, 2013, broken down by sub-categories. The table includes both the relevant sums and the upper and lower bounds of the 95 % confidence interval.

Category	GHG	Grassland (in a strict sense) Emissions, 2013 [Gg CO_2-eq.]			[%]	
		Emission	2.5 perc.	97.5 perc.	2.5 perc.	97.5 perc.
Grassland (in a strict sense)$_{total}$		23665.6	14,374.0	30,292.6	42.0	22.2
Mineral soils	CO_2	-1,680.9	-1,302.2	-2,333.6	22.5	38.8
	N_2O	0	0	0	0	0
Organic soil	CO_2	24,294.0	12,929.1	30,146.1	46.8	24.1
	N_2O	IE	IE	IE	IE	IE
	CH_4	514.8	310.9	1,640.0	39.6	218.5
Biomass	CO_2	424.3	363.3	499.9	14.4	17.8
Litter / dead wood	CO_2	113.3	106.6	133.8	5.9	18.1

Category	GHG	Woody grassland, emissions, 2013 [Gg CO_2-eq.] Emission	2.5 perc.	97.5 perc.	[%] 2.5 perc.	97.5 perc.
Woody grassland$_{total}$		-889.4	-705.1	-1,094.6	20.7	23.1
Mineral soils	CO_2	-221.0	-185.0	-291.9	16.3	32.1
	N_2O_{direct}	**4.3**	4.0	9.3	91.5	214.5
	$N_2O_{indirect}$	**1.0**	0	2.9	100	296.8
Organic soil	CO_2	197.2	177.2	225.9	10.2	14.6
	N_2O	15.6	8.5	30.9	45.4	97.4
	CH_4	2.8	1.5	16.4	46.0	489.0
Biomass	CO_2	-941.6	-637.4	-1,270.2	32.3	34.9
Litter / dead wood	CO_2	52.2	49.1	60.8	5.9	16.6

In comparison to the pertinent values for 2013, the time series for total emissions from grassland (in the strict sense) includes emissions that have increased by 6.9 % with respect to the base year. The time series for total emissions is dominated by emissions from organic soils; in general, it reflects the area changes in such soils over time. The highest emissions occurred in 2005. Since then, they have been decreasing, as a result of intensified transfers of organic grassland areas into other land-use categories (Cropland, in particular, accounting for 54 % of the change area, and with a trend of +20% since 2005). Along with emissions from organic soils, emissions from biomass and dead organic matter also affect the trend – as a result of deforestation measures and, more recently, of decreases in such measures. Unlike such sources, mineral soils function as a sink. Over time, that sink function exhibits a highly significant negative trend; it has decreased by 22.1 % with respect to the base year. This is due to a decrease in conversion of Forest Land, Cropland, Wetlands and Other Land to Grassland (-22.4 %). Decreases in transfers of land from Cropland, accounting for 70.4 % of that sum, are the main factor responsible for the decrease in the sink function.

The shapes of the time-series plots – especially the noticeable changes they show – are due primarily to the changes in area data that have occurred as of the relevant explicitly defined survey dates. This applies especially to the sub-category woody grassland.

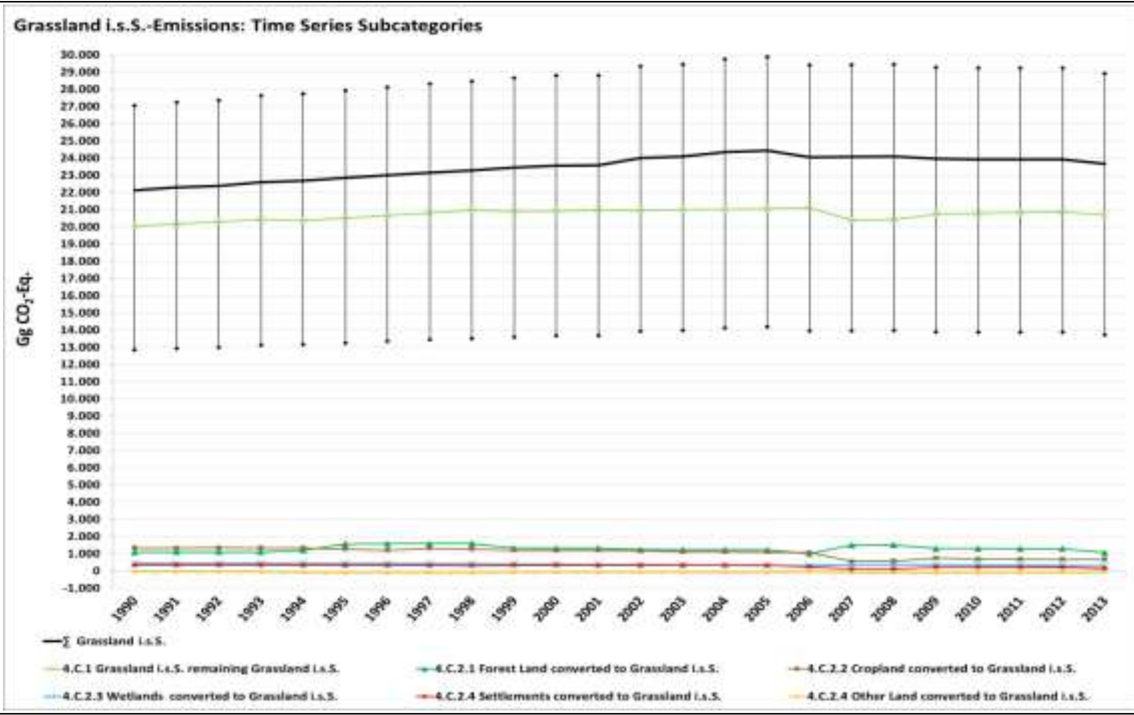

Figure 65: CO_2 emissions [Gg CO_2 eq.] from grassland (in a strict sense), as a result of land use and land-use changes, in Germany, 1990 – 2013, by sub-categories

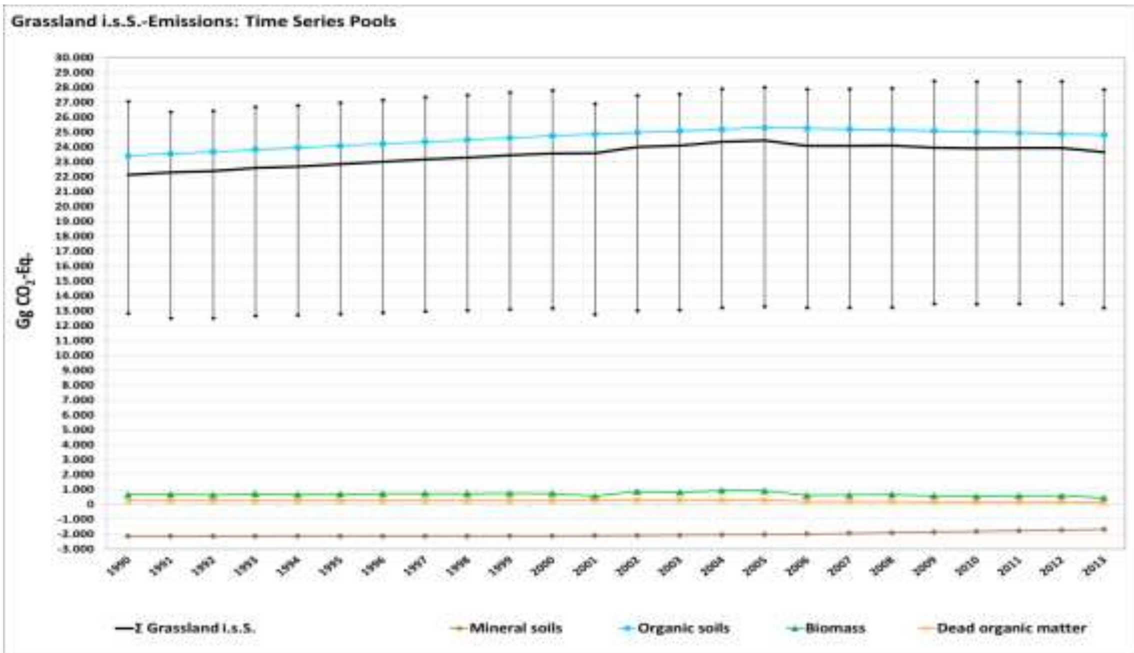

Figure 66: CO_2 emissions [Gg CO_2 eq.] from grassland (in a strict sense), as a result of land use and land-use changes, in Germany, 1990 – 2013, by pools

Unlike Grassland (in the strict sense), the sub-category Woody grassland functions as a CO_2 sink (-889.4 CO_2-eq.;Table 287 and Figure 65 / Figure 66), since negative emissions, and emissions near 0, predominate in both the "remaining" category and in all transfer categories. This is due to the effects of biomass, which tends to increase considerably in connection with land-use change leading to woody grassland (cf. Table 250), and which, which a share of 106 % of the net emissions, dominates the categories in this sub-category. The transfer category Forest Land to Woody grassland is an exception, since forests have larger biomass stocks than woody grassland does. In this category, CO_2 releases from dead organic matter also occur. The sink effect is intensified via CO_2 removals into mineral soils (share of net emissions: 24 %); they completely offset the emissions from the organic soils.

The plots of the time series, as shown in Figure 67 and Figure 68, show that the sink function has increased by 20 % with respect to the base year. The plots exhibit no unambiguous trend. On the other hand, they reflect the set-aside phase that occurred in the agricultural sector as of the turn of the millennium, just as they reflect the growing agricultural intensification that has occurred in recent years. As a result of that intensification, more and more of the set-aside areas have been returned to cultivation, and conversion of woody grassland areas for settlement purposes has also increased. This can been seen in the shape of the pluts for the categories for conversion of Cropland, Grassland (in the strict sense) and Settlements to woody grassland(Figure 67).

The shapes of the time-series plots – especially the noticeable changes they show – are due primarily to the changes in area data that have occurred as of the relevant explicitly defined survey dates.

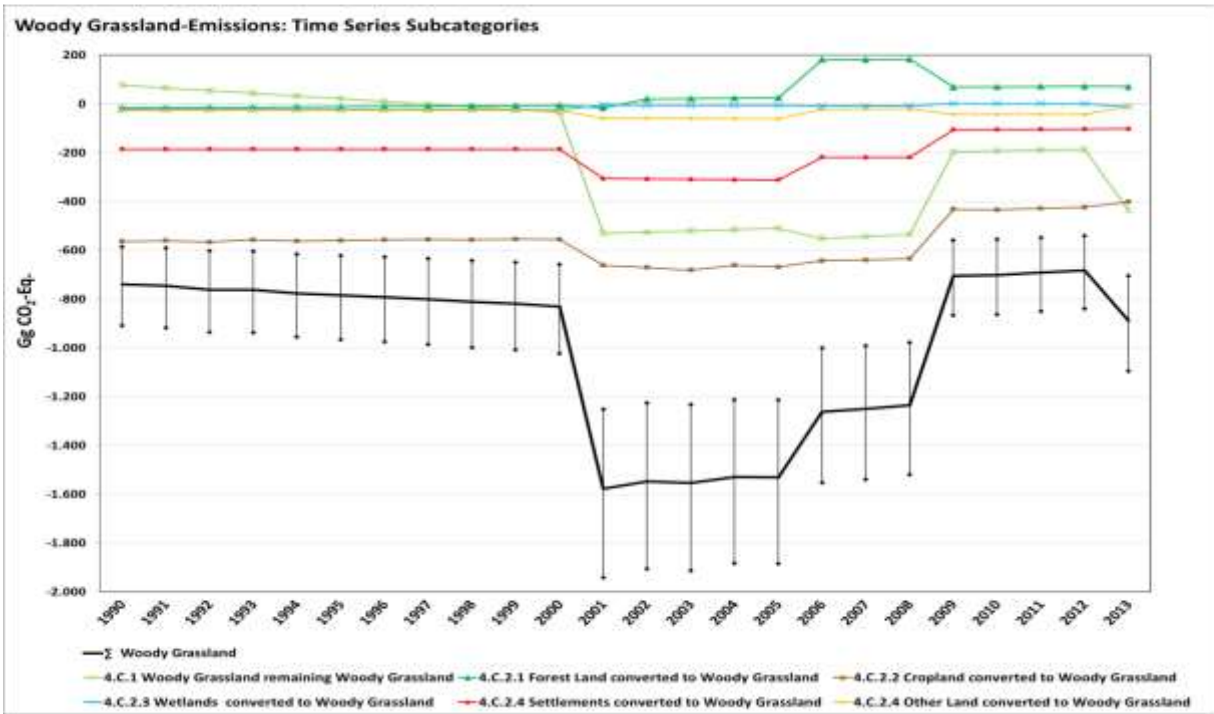

Figure 67: CO_2 emissions [Gg CO_2 eq.] from Germany's woody grasslands, as a result of land use and land-use changes, 1990 – 2013, by sub-categories

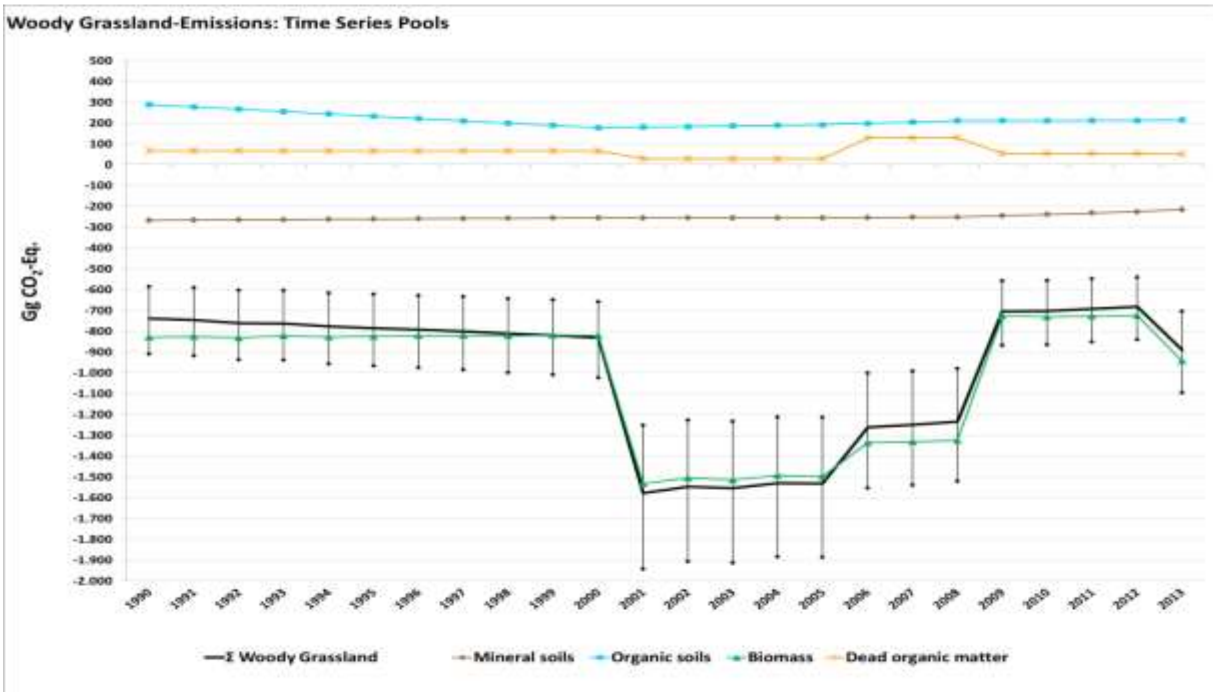

Figure 68: CO_2 emissions [Gg CO_2 eq.] from Germany's woody grasslands, as a result of land use and land-use changes, 1990 – 2013, by pools

6.6.2 Methodological issues (4.A.1)

6.6.2.1 Data sources

- Statistisches Bundesamt, Fachserie 3, Reihe 3, Land- und Forstwirtschaft, Fischerei, Landwirtschaftliche Bodennutzung und pflanzliche Erzeugung (Federal Statistical Office, Fachserie 3, Reihe 3, agriculture and forestry, fisheries, agricultural soil use and crop cultivation; various years)
- Statistisches Bundesamt, Fachserie 3, Reihe 3.2.1, Land- und Forstwirtschaft, Fischerei, Wachstum und Ernte – Feldfrüchte (Federal Statistical Office, Fachserie 3, Reihe 3, agriculture and forestry, fisheries, growth and harvests – crops; various years)
- Statistisches Bundesamt, Fachserie 3, Reihe 3.1.2, Land- und Forstwirtschaft, Fischerei,– Bodennutzung der Betriebe (Federal Statistical Office, Fachserie 3, Reihe 3, agriculture and forestry, fisheries – soil use by sectoral operations; various years)
- 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4 – Agriculture, Forestry and Other Land Use (IPCC 2006)
- "Ordinance on application of fertilisers, soil additives, culture substrates and plant additives according to the principles of good practice in fertilization (Ordinance on Fertilisation – Düngeverordnung (DüV))" (Ordinance on Fertilisation in the version as promulgated 27 February 2007 (Federal Law Gazette I, p. 221), last amended by Article 18 of the Act of 31 July 2009 (Federal Law Gazette I p. 2585) (Federal Law Gazette 2009)
- Interim report in the research project "Methodenentwicklung zur Erfassung der Biomasse mehrjährig verholzter Pflanzen außerhalb von Wäldern“ ("Development of methods for determining the biomass of plants, outside of forests, with multiple years of wood growth") (PÖPKEN 2011)

6.6.2.2 Biomass

For calculation of carbon-stock changes in biomass, in connection with land-use changes to and from grassland, constant (over time) carbon stocks were determined for the sub-categories "grassland (in a strict sense)" and "woody grassland". In addition, conversions from grassland (in a strict sense) to woody grassland and vice-versa are treated like land-use changes, and listed as such in the CRF tables (4.C.1).

No carbon-stock changes are given for the biomass of areas in the sub-categories grassland (i.s.s.) and woody grassland, since the carbon fluxes and the wood biomass in these categories are assumed to be in equilibrium; under the gain-loss method, therefore, $\Delta C = 0$ (Equation 2.7 in the 2006 IPCC Guidelines). Consequently, "NO" (not occurring) has been entered in the CRF Table 4.C.1, under the headings "living biomass" and "dead organic matter", for the transfer categories of grassland (in a strict sense) and woody grassland. This assumption is made in light of the representative "equilibrium carbon stocks" determined for Germany's field and hedge trees/shrubs. The biomass levels of the field and hedge trees/shrubs typically found in Germany have been determined in a research project focusing on a broad and diverse range of hedges, and differentiating hedges by criteria such as species composition, growth density, height and age (cf. Chapter 6.6.2.2.2). With this approach, it was possible to determine representative equilibrium carbon stocks for field and hedge trees/shrubs, since the approach included summation over all age classes, plant types and plantation structures and combinations. Since the rotation periods for woody plants tend to be relatively short (about 10 – 12 years), such plantations tend to rejuvenate frequently. Such rejuvenation occurs from the pool used to derive the pertinent emission factors, however. The processes of planting, growth, pruning and rejuvenation reach a state of dynamic equilibrium. In the case of land-use changes leading to land areas with woody grassland, the carbon stocks in the biomass of the relevant woody plants are thus reported completely in the year of the land-use change. With regard to changes in carbon stocks, such equilibria are disturbed only through changes in the relevant surveyed areas. Such changes are recorded as land-use changes, and the pertinent sources and sinks are reported.

The manner in which CO_2 emissions from biomass, as a result of land-use changes, are calculated is presented in Chapter 6.1.2.3, while the method used to determine activity data is described in Chapter 6.3. The emission factors for the period 1990 to 2013, and their uncertainties, are shown in Table 310 and Table 311 in Chapter 6.6.3.

6.6.2.2.1 Grassland (in a strict sense) (i.s.s.)

Grassland (in a strict sense) is free of trees and shrubs. The carbon stocks in the above-ground and below-ground biomass of grassland (in a strict sense) have been calculated on the basis of the Federal Statistical Office's harvest statistics. The harvests and areas of all meadows, mowed pastures, alpine pastures and rough pastures enter into the calculations for grassland (in a strict sense). Since no significant trend emerged in the harvest covered by the harvest statistics, constant (over time) carbon stocks were calculated. For annual crops, the dry biomass of individual plant parts is derived from harvest data, pursuant to HAENEL et al. (2012), using relevant ratios and water-content data (obtained from various sources).

For calculation of biomass carbon stocks, an average carbon content of 45 % by weight was assumed – and used instead of the IPCC default value (50 % by weight) – since OSOWSKI et al. (2004) give carbon contents of 44 – 48 % by weight for plants in central Europe and since

PÖPKEN (2011), in her studies of cultivated trees (carried out for the German inventory), also found average values of 45 to 46 % by weight.

The area-related carbon stocks obtained for grassland (in a strict sense) are shown in Table 308.

Table 308: Area-related carbon stocks [Mg C ha^{-1}] of grassland (in a strict sense) (± half of the 95 % confidence interval)

Grassland (in a strict sense)	Carbon stocks [Mg C ha^{-1}] Bio$_{total}$	Bio$_{above-ground}$	Bio$_{below-ground}$
Grassland (in a strict sense)	6.69 ± 1.70	4.36 ± 0.28	2.33 ± 1.67

6.6.2.2.2 Woody grassland

In order to determine carbon stocks in hedges, PÖPKEN (2011) has studied 40 hedges to date, working in the framework of the research project "Methodenentwicklung zur Erfassung der Biomasse mehrjährig verholzter Pflanzen außerhalb von Waldflächen" ("Development of methods for determining the biomass of plants, outside of forests, with multiple years of wood growth") . The hedges studied to date vary widely in their characteristics:

1. Age

- About 4 – 20 years old

2. Dimensions

- Height, about 2 – 9 m
- Depth, about 1 – 6 m
- Length, about 100 – 500 m

3. Species composition

- Typical hedge plants, such as dog rose (Rosa canina), blackthorn/sloe (Prunus spinosa), common hazel (Corylus avellana), elder (Sambuccus spec.), hawthorn (Crataegus spec.), honeysuckle (Lonicera spec.), willow (Salix spec.).
- Trees, such as field maple (Acer campestre), common hornbeam (Carpinus betulus), willow (Salix spec.), beech (Fagus silvatica), linden (Tilia spec.) and elm (Ulmus spec.),

As a result, the study has included a representative spectrum of relevant field trees and shrubs. Laboratory analysis of samples taken of the various species in question included measurement of weight, water content and carbon content. That, in turn, made it possible, in connection with size data for the relevant fields, to determine absolute and area-related carbon stocks (cf. Table 309). Via regression, carried out on the basis of these data, a highly significant correlation between the average carbon stocks of the above-ground biomass of hedges and the ages of hedges was found:

$$\mathbf{C_{above} = 1.5506 * X^{1.6015}}$$

R^2 = 0.843; half of the 95 % confidence interval: ± 65.7 %

C_{above}: Average carbon stocks of above-ground biomass in hedges [Mg C ha^{-1}]

X: Hedge age [a]

With this equation, the average carbon stocks in the above-ground biomass of hedges was determined for each year of the rotation period (12 years). For reasons of nature conservation, the study carried out by PÖPKEN (2011) was able to survey only above-ground biomass. For this reason, the below-ground biomass was estimated via the formula that MOKANY et al. (2006) derived via regression. That then made it possible, for each of the age classes in question, to determine below-ground biomass on the basis of above-ground biomass.

$$\mathbf{Bio_{below} = 0.489 * Bio_{above}^{0,890}} \text{ (MOKANY et al. 2006)}$$

$R^2 = 0.93$

Bio_{below}: Below-ground biomass in Mg C ha^{-1}

Bio_{above}: Above-ground biomass in Mg C ha^{-1}

The total stocks per age class are then obtained via

$$\mathbf{C_{total\_AK} = C_{above\text{-}AK} + C_{below\_AK}}$$

C_{total_AK}: Average carbon stocks in the total biomass of hedge plants of a single age class [Mg C ha^{-1}]

C_{above_AK}: Average carbon stocks in the above-ground biomass of hedge plants of a single age class [Mg C ha^{-1}]

C_{below_AK}: Average carbon stocks in the below-ground biomass of hedge plants of a single age class [Mg C ha^{-1}]

The average value for all age classes of a given rotation period then yields the average equilibrium carbon stocks in Germany's hedges. That figure, in turn, is used, as an emission factor, as a basis for the inventory calculations; cf. Table 295.

Table 309: Area-based carbon stocks [Mg ha^{-1} (95 % confidence interval)] in the biomass of trees and shrubs in woody grassland

Trees and shrubs in woody grassland	Carbon stocks [Mg C ha^{-1}]		
	$Bio_{above\text{-}ground}$	**$Bio_{below\text{-}ground}$**	**Bio_{total}**
Trees and shrubs	32.69 (10.46 - 55.27)	10.47 (3.16 - 18.11)	43.16 (19.77 - 67.00)

6.6.2.3 Mineral soils

No change in carbon stocks in mineral soils is listed for areas remaining as cropland. The constancy of carbon stocks is substantiated by the results obtained on 42 regional long-term-trial areas (HÖPER und SCHÄFER 2012, FORTMANN et al. 2012 and BLU 2011). The pertinent long-term observations cover a period of 20 – 25 years. During that period, most of the areas studied exhibited no changes in the carbon stocks in mineral soils. Some soils showed slight reductions, while others exhibited slight increases that nearly exactly offset the decreases, both in terms of numbers and in absolute terms. In CRF Table 4.C.1, "NO" (not occurring) has thus been entered in the spaces "carbon-stock changes in mineral soils" in the final-use categories grassland (in a strict sense) and woody grassland. The manner in which CO_2 emissions resulting from conversions leading to grassland (in a strict sense) and to woody grassland are calculated is described in Chapter 6.1.2.1, while the pertinent emission factors are shown in Table 310 and Table 311 in Chapter 6.6.3, and derivation of the emission factors is described in Chapter 19.4.2.

6.6.2.4 Organic soils

In the land-use category Grassland, CO_2, CH_4 and N_2O emissions from organic soils are reported; nitrous oxide emissions are reported only for the sub-category woody grassland. N_2O emissions from organic soils under grassland (in a strict sense) are reported as part of the "Agriculture" sector, under CRF Table 3.D.a.6 "Cultivation of Histosols" (cf. Chapter 6.6.2). To prevent double-counting, therefore, N_2O emissions from organic soils that result from conversions to grassland (in a strict sense) are listed in the LULUCF tables with the notation key "IE". The methods used to calculate emissions from organic soils, and to derive the relevant emission factors, are described in Chapter 6.1.2.

The annual emissions following land-use changes leading to grassland (in a strict sense) are calculated with the same procedure used for emissions from organic soils in the final-use sub-category grassland (in a strict sense). A similar approach is taken with emissions from organic soils following land-use changes leading to woody grassland; they are calculated in same way that emissions from woody grassland remaining woody grassland are calculated. The emissions in the non-transfer categories ("remaining") are listed in CRF Table 4.C.1, while the emissions resulting from land-use changes are listed in Table 4.C.2.1 - 4.C.2.5. Methane emissions from organic soils, and from drainage ditches, are included in the figures in CRF Table 4.II.C.

6.6.3 Uncertainties and time-series consistency (4.C)

Table 310 and Table 311 show the uncertainties relative to the emission factors for the grassland sub-categories grassland (in a strict sense) and woody grassland. As a rule, the relevant distribution functions show a log-normal distribution, and they are characterised by their upper and lower boundaries. The uncertainties relative to mineral soils are of the same order of magnitude for both sub-categories. With regard to biomass, the uncertainties for the emission factors are higher for the "woody grassland" sub-category. Those uncertainties reflect the great diversity of relevant woody grassland in Germany. With respect to the uncertainties for the emission factors for CO_2, nitrous oxide and methane from organic soils, the statements made in Chapter 6.6.3 apply.

The uncertainties shown in Table 426 in Chapter 19.4.4 for the activity data have a normal distribution, with values between 1.6 – 139 % for half of the 95 % confidence interval. In this case as well, the uncertainty depends on the sample size, i.e. on the area share being considered. Weighted by area, the total uncertainty for activity data in the grassland category is 1.5 %.

In terms of total emissions, Table 426 in Chapter 19.4.4 shows that emissions from organic soils under grassland, like those from biomass in this category, contribute significantly to the emissions and total uncertainty of the LULUCF inventory.

Table 310: Emission factors [Mg C ha^{-1} a^{-1}], with uncertainties [% of location scale], as used for calculation of 2013 GHG emissions from grassland (in a strict sense)

Grassland$_{\text{in the narrow sense}}$ Land use$_{\text{before}}$ Mineral soils CO_2-C[107]	Area Land use$_{\text{after}}$	Emission factor [Mg C ha^{-1} a^{-1}]	Boundaries upper [%]	lower [%]
Forest land	Grassland$_{\text{i.s.s.}}$	0.87	25.6	42.7
Cropland	Grassland$_{\text{i.s.s.}}$	0.87	29.6	49.1
Woody grassland	Grassland$_{\text{i.s.s.}}$	0.21	31.5	56.9
Terr. wetlands	Grassland$_{\text{i.s.s.}}$	0.17	31.8	47.4
Waters	Grassland$_{\text{i.s.s.}}$	0.00	45.9	77.9
Settlements	Grassland$_{\text{i.s.s.}}$	0.94	32.6	57.5
Other land	Grassland$_{\text{i.s.s.}}$	1.09	32.6	59.7
Organic soil[108]		**[Mg C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Grassland (in a strict sense)	**CO_2**	25.13	55.4	28.4
Grassland (in a strict sense)	**N_2O**	1.17	99.4	222.7
Grassland (in a strict sense)	**CH_4**	0.53	46.9	258.6
Biomass[109]		**[Mg C ha^{-1} 1 a^{-1}]**	**[%]**	**[%]**
Forest land	Grassland$_{\text{i.s.s.}}$	-47.97	20.8	20.8
Cropland	Grassland$_{\text{i.s.s.}}$	-0.84	12.9	12.9
Woody grassland	Grassland$_{\text{i.s.s.}}$	-36.48	47.1	47.9
Terr. wetlands	Grassland$_{\text{i.s.s.}}$	-12.16	32.1	32.7
Waters	Grassland$_{\text{i.s.s.}}$	6.69	25.4	25.4
Settlements	Grassland$_{\text{i.s.s.}}$	-5.78	31.9	32.4
Other land	Grassland$_{\text{i.s.s.}}$	6.69	25.4	25.4
Dead organic matter[110]		**[Mg C ha^{-1} 1 a^{-1}]**	**[%]**	**[%]**
Forest land	Grassland$_{\text{i.s.s.}}$	-20.70	5.9	5.9

Forest land, cropland: annually variable; all other factors are constant

Table 311: Emission factors [Mg C ha^{-1} a^{-1}], with uncertainties [% of location scale], as used for calculation of GHG emissions in 2013 from woody grassland

Woody grasslands Land use$_{\text{before}}$ Mineral soils CO_2-C[111]	Area Land use$_{\text{after}}$	Emission factor [Mg C ha^{-1} a^{-1}]	Boundaries upper [%]	lower [%]
Forest land	Woody grassland	0.60	23.4	44.5
Cropland	Woody grassland	0.66	27.9	51.1
Grassland (in a strict sense)	Woody grassland	-0.21	31.5	56.9
Terr. wetlands	Woody grassland	-0.04	30.7	49.1
Waters	Woody grassland	0.00	42.9	83.3
Settlements	Woody grassland	0.73	31.2	85.0
Other land	Woody grassland	0.88	31.1	62.0

[107] Calculation covers a 20-year period; stock change: positive ≙ sink; negative ≙ source

[108] Annual calculation; emission: positive ≙ source; negative ≙ sink

[109] Calculation only for first year of land-use change, stock change: positive ≙ sink; negative ≙ source

[110] Calculation only for first year of land-use change, stock change: positive ≙ sink; negative ≙ source

[111] Calculation covers a 20-year period; stock change: positive ≙ sink; negative ≙ source

Mineral soil, N_2O_{direct}[112]		**[kg N_2O ha^{-1} a^{-1}]**	**[%]**	**[%]**
Grassland (in a strict sense)	Woody grassland	0.263	91.6	213.9
Terr. wetlands	**Woody grassland**	0.042	91.3	211.9
Mineral soil, $N_2O_{indirect}$[113]		**[kg N_2O ha^{-1} a^{-1}]**	**[%]**	**[%]**
Grassland (in a strict sense)		0.059	100	296.6
Terr. wetlands		0.009	100	295.2
Organic soil[114]		**[Mg C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Woody grassland	**CO_2**	9.33	21.0	24.6
Woody grassland	**N_2O**	0.74	93.8	222.7
Woody grassland	**CH_4**	0.13	95.2	1011.6
Biomass[115]		**[Mg C ha^{-1} 1 a^{-1}]**	**[%]**	**[%]**
Forest land	Woody grassland	-11.50	34.0	34.5
Cropland	Woody grassland	35.64	46.2	47.1
Grassland (in a strict sense)	Woody grassland	36.48	47.1	47.9
Terr. wetlands	Woody grassland	24.32	33.9	34.5
Waters	Woody grassland	43.16	54.2	55.2
Settlements	Woody grassland	30.70	43.4	44.2
Other land	Woody grassland	43.16	54.2	55.2
Dead organic matter[116]		**[Mg C ha^{-1} 1 a^{-1}]**	**[%]**	**[%]**
Forest land	Woody grassland	-20.70	5.9	5.9

Forest land, cropland: annually variable; all other factors are constant

Table 312: Uncertainties for emission factors [2.5 and 97.5 percentile, in % of location scale] for emissions from organic soils under woody grassland, 2013

Land use	**Greenhouse gas**	**Emission factor**	**Boundaries**	
			lower	**upper**
Organic soil[117]		**[Mg CO_2-eq. ha^{-1} a^{-1}]**	**[%]**	**[%]**
Woody grassland	**CO_2**	9.33	21.0	24.6
Woody grassland	**N_2O**	0.74	93.8	222.7
Woody grassland	**CH_4**	0.13	95.2	1011.6

For both grassland (in the strict sense) and woody grassland, the calculations are spatially and chronologically consistent and complete for the entire report period, 1990 – 2013.

6.6.4 Category-specific quality assurance / control and verification (4.C)

With regard to quality control and quality assurance, we refer to Chapter 6.1.3.

The data sources used in preparation of this inventory fulfill the review criteria of the QSE manual for data sources (QSE-Handbuch für Datenquellen). Quality assurance for input data (ATKIS®, BÜK, official statistics) is the responsibility of the relevant data administrators (cf. the pertinent documentation in the inventory description).

[112] Calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink

[113] Calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink

[114] Annual calculation; emission: positive ≙ source; negative ≙ sink

[115] Calculation only for first year of land-use change, stock change: positive ≙ sink; negative ≙ source

[116] Calculation only for first year of land-use change, stock change: positive ≙ sink; negative ≙ source

[117] Annual calculation; emission: positive ≙ source; negative ≙ sink

The emissions-calculation results as presented in the present report cannot be compared with other relevant data sources for Germany, since no such other data sources exist that meet applicable requirements, i.e. provide complete coverage, are comprehensive and are independent of the methods and data sources described in the present report.

As the intra-European comparison of implied emission factors presented in Table 313 shows, Germany's IEF for CO_2 from drainage of organic soils under grassland is comparable to those of neighbouring countries with similarly intensive bog use, such as Switzerland and the Netherlands. That value is a mixed, area-weighted value, however, consisting of -6.85 Mg C ha^{-1} a^{-1} from grassland (in a strict sense) and -2.61 Mg C ha^{-1} a^{-1} from woody grassland (Chapter 6.6.2.4). In the case of land-use changes leading to grassland, the emission factor used for organic soils is immediately the same as that used for grassland remaining grassland.

In the category "grassland remaining grassland", the carbon-stock changes in mineral soils and in biomass, as reported for Germany, refer to changes between grassland (in a strict sense) and woody grassland. The mean emission factors are very low, since only a small area share is involved. Such changes are handled very differently from country to country, and thus the relevant mean emission factors of different countries cannot be directly compared.

In Germany, the land-use changes to grassland have produced a strong C sink in mineral soils; the pertinent values are comparable to those of two countries that share borders with Germany, Austria and France. All in all, the German IEF is somewhat higher than the average of all values listed in Table 313. The German IEF for the biomass in the transfer categories differs markedly from those of neighbouring countries, however. It differs in terms of its order of magnitude, and it differs in terms of its sign, which marks this category in Germany as a sink. The reason for this is the mixed value for the grassland sector on which the table is based; that value reflects the large country's large biomass stocks in the sub-category woody grassland. A comparison of just the values for grassland (in the strict sense) reveals that Germany's value – which amounted to -0.16 in Germany in 2013 – is comparable to those of the neighbouring countries in terms of both order of magnitude and sign.

Table 313: Comparison of implied emission factors (IEF) for different grassland pools, for Germany and for neighbouring countries in Europe, for the year 2012 (exception: Germany, NIR 2015: the 2013 figure is used, for comparison)

Implied emission factors (IEF), grassland, NIR 2014	Grassland remaining grassland			Land-use changes leading to grassland			
	Organic soils	Mineral soils	Biomass	Organic soils	Mineral soils	Biomass	Dead org. matter
	Mg C ha^{-1}						
Austria	-0.25	0.00	NO	NO	0.88	-0.67	-0.40
Belgium	-2.50	-0.16	NO	NO	1.50	-0.29	-0.02
Denmark	-0.88	IE,NA,NO	-0.19	IE,NA	-0.02	-0.62	-0.04
France	NO	NO	0.00	-2.41	1.10	-0.13	-0.02
UK	IE,NO	0.11	NO	-0.25	0.62	-0.06	-0.01
Netherlands	-6.54	NO	NE	NE	0.56	-0.28	-0.22
Poland	-0.25	-0.02	NO	IE,NO	0.11	NO	NO
Czech Republic	NO	0.00	NO	NA,NO	0.49	-0.01	0.00
Switzerland	-8.89	0.01	0.00	-8.61	0.60	-0.99	-0.37
Germany, NIR 2014	-4.73	0.00	0.00	-3.91	0.78	-0.10	-0.20
Germany, NIR 2015	**-6.78**	**0.001**	**0.031**	**-6.63**	**0.82**	**0.16**	**-0.05**

Positive: C sink; negative: C source

6.6.5 Category-specific recalculations (4.C)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

Because the 2006 IPCC Guidelines (IPCC 2006) have been implemented in this year's submission, a complete recalculation of the inventory was carried out, on the basis of those Guidelines. It covered all category-specific time series for the entire reporting period, 1990 – 2013.

6.6.6 Category-specific planned improvements (4.C)

Cf. Chapter 6.5.6.

No further improvements, in addition to those previously announced, are planned. Information about the implementation status of planned improvements in the LULUCF sector is presented in Chapter 6.1.4.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

6.7 Wetlands (4.D)

6.7.1 Category description (4.D)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/-/2	**4.D Wetlands**		**CO2**	**2.626,5**	**(0,22%)**	**2.453,0**	**(0,26%)**	**-6,6%**
-/-	4.D Wetlands		CH4	11,6	(0,00%)	12,3	(0,00%)	5,9%
-/-	4.D Wetlands		N2O	10,5	(0,00%)	11,2	(0,00%)	7,6%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	RS/NS	CS
N_2O	Tier 2	RS/NS	CS
CH_4	Tier 2	RS/NS	CS

Pursuant to Tier-2 analysis, the category Wetlands is a key category for CO_2 emissions.

In Germany, the "wetlands" category includes the country's few undrained semi-natural bogs that are largely free of anthropogenic impacts. It also includes other wetlands and water bodies without anthropogenic greenhouse-gas emissions and the peat-extraction areas used for production of horticultural peat.

CO_2 emissions from regulated waters with widely fluctuating water levels (flooded lands) are reported pursuant to the IPCC Guidelines 2006, i.e. only as emissions from biomass, as a result of land-use changes. Methane emissions are thus not subject to reporting obligations. Emissions from peat extraction are reported solely in the category "Wetlands remaining Wetlands". The relevant changes in carbon stocks in above-ground and below-ground biomass, and in soils, are reported in the various land-use-change categories. The results of the emissions calculations for the year 2013 are shown in Table 314, while the emissions trends, broken down by pools and sub-categories, are presented in Figure 69 and Figure 70.

Table 314: CO_2, N_2O and CH_4 emissions [Gg CO_2-eq.] from Germany's wetlands, 2013. The table includes both the relevant sums and the upper and lower bounds of the 95 % confidence interval.

Category	GHG	Peat extraction, 2013 Emission	[Gg CO_2-eq.] 2.5 perc.	97.5 perc.	[%] 2.5 perc.	97.5 perc.
Total, peat extraction		2,172.7	1,365.4	3,141.4	37.2	44.6
Mineral soils	CO_2	NO	NO	NO	NO	NO
	N_2O	NO	NO	NO	NO	NO
Organic soil	CO_2	2,159.3	1,149.1	2,679.4	46.8	24.1
	N_2O	7.9	2.9	12.9	63.3	63.3
	CH_4	5.6	1.9	10.7	65.3	92.9
Biomass	CO_2	/	/	/	/	/
Litter / dead wood	CO_2	/	/	/	/	/
Category	**GHG**	**Waters, 2013 Emission**	**[Gg CO_2-eq.] 2.5 perc.**	**97.5 perc.**	**[%] 2.5 perc.**	**97.5 perc.**
Total, waters		43.3	38.1	48.6	12.1	12.2
Mineral soils	CO_2	/	/	/	/	/
	N_2O	/	/	/	/	/
Organic soil	CO_2	/	/	/	/	/
	N_2O	/	/	/	/	/
	CH_4	/	/	/	/	/
Biomass	CO_2	43.3	36.6	51.1	15.4	17.9
Litter / dead wood	CO_2	/	/	/	/	/
Category	**GHG**	**Terrestrial wetlands, 2013 Emission**	**[Gg CO_2-eq.] 2.5 perc.**	**97.5 perc.**	**[%] 2.5 perc.**	**97.5 perc.**
Total, terrestrial wetlands		260.6	228.9	292.5	12.1	12.2
Mineral soils	CO_2	-4.8	-3.6	-7.0	25.5	46.4
	N_2O_{direct}	0.8	0.7	1.7	91.7	214.7
	$N_2O_{indirect}$	0.2	0	0.5	100	297.2
Organic soil	CO_2	320.1	219.5	374.6	31.4	17.0
	N_2O	2.5	1.1	5.7	56.4	126.6
	CH_4	6.7	4.9	16.6	26.6	146.9
Biomass	CO_2	-64.9	-54.9	-76.5	15.4	17.9
Litter / dead wood	CO_2	0	0	0		

In 2013, a total of 2,172.7 Gg CO_2-eq. were released from wetlands. (95 % confidence interval: 1,365.4 - 3,141.4 Gg CO_2-eq.). Table 314 shows how the level of emissions from the land-use category wetlands is due primarily to the level of emissions from organic soils (101 %) and that those emissions, in turn, consist largely of CO_2 releases via peat extraction (86 %). Releases of methane (0.5 %) and nitrous oxide (0.5 %) are very low in terms of the summed total emissions. On the other hand, the sink functions performed by biomass (-0.9 %) and mineral soils (-0.2 %) are also very low.

Emissions from industrial peat extraction are divided into emissions that occur in extraction areas, during peat extraction (on-site emissions), and emissions that are released during application of peat products (off-site emissions). In 2013, the latter amounted to 2,042.04 ± 800.5 Gg CO_2-eq. and thus were the main factor responsible for the magnitude of total emissions from peat extraction (94 %). The on-site emissions, at 130.7 Gg CO_2-eq., (-9.9 % / +11.5 %), are relatively low by contrast. Their predominant component is CO_2 (89.7 %); methane (4.3 %) and nitrous oxide emissions (6.1 %) play marginal roles.

As the time series in Figure 69 and Figure 70 show, total emissions increased by 6.1 % in 2013, with respect to the base year, but the individual changes remained incremental overall. The trend, in which peat extraction is the predominant factor, reflects the annual quantities of peat production.

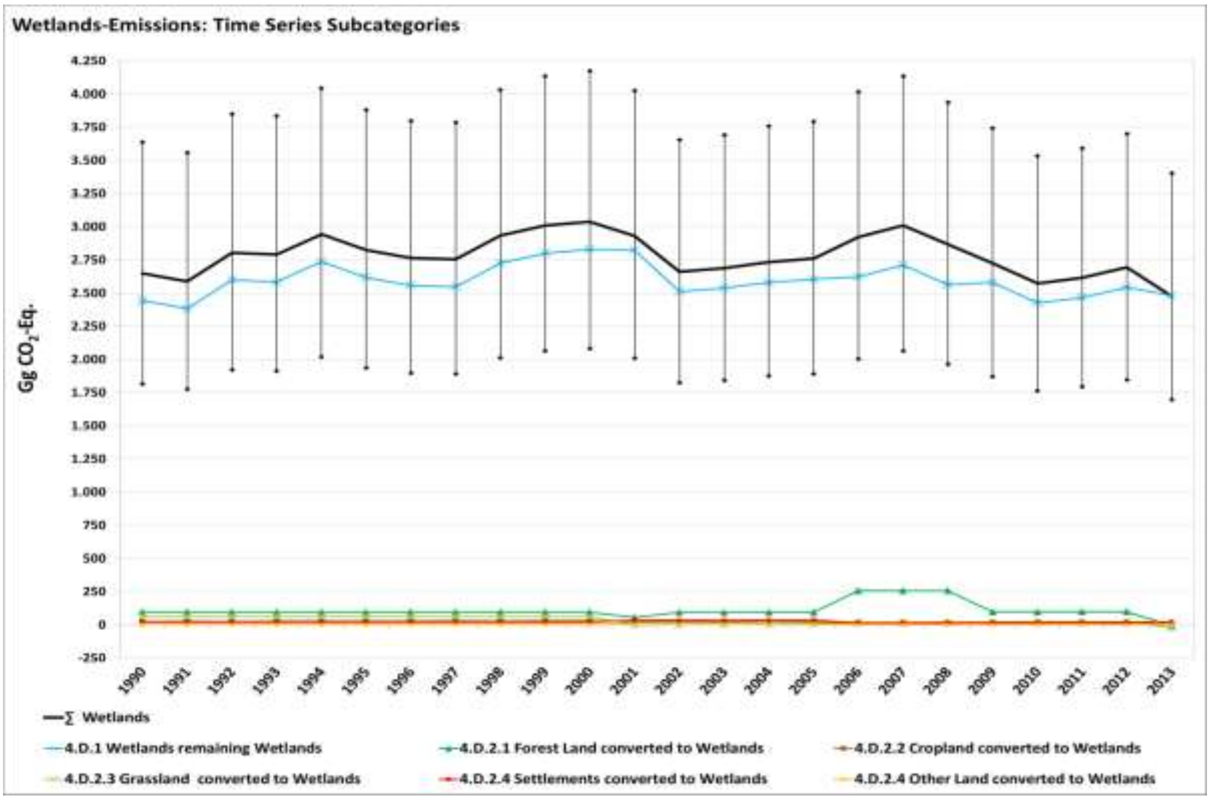

Figure 69: CO_2 emissions [Gg CO_2-Eq.] from Germany's wetlands, as a result of land use and land-use changes, 1990 – 2013, by sub-categories

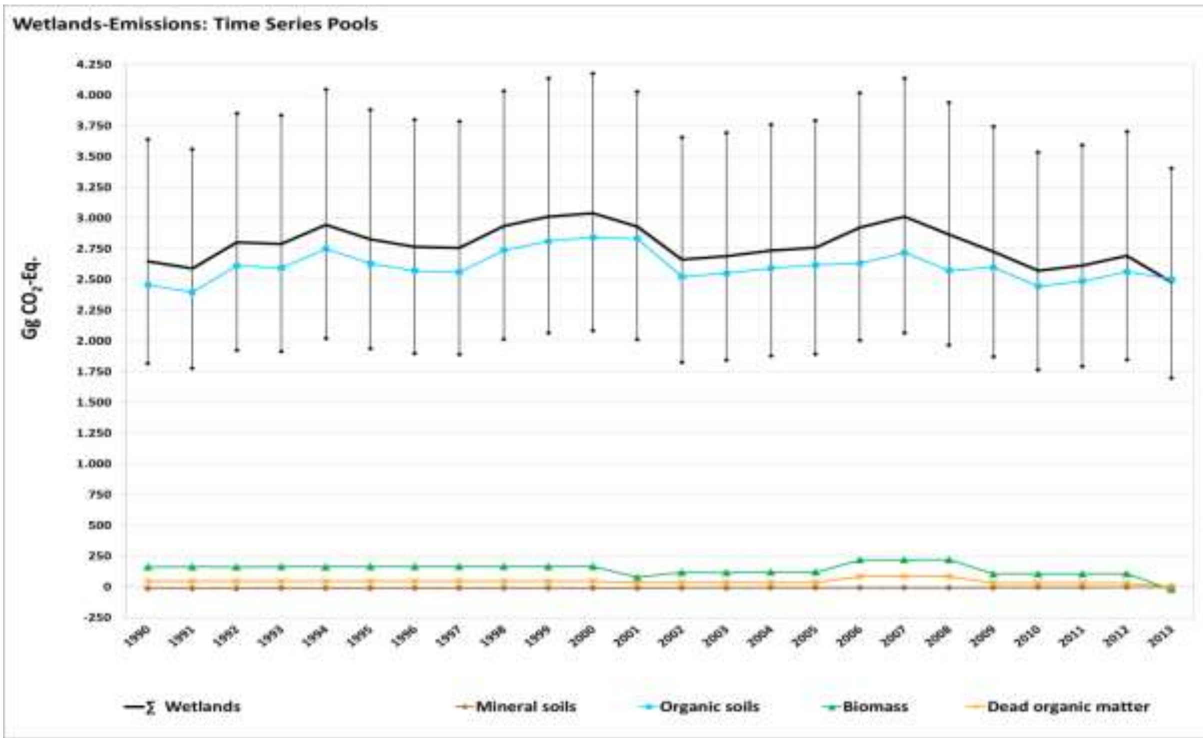

Figure 70: CO_2 emissions [Gg CO_2-Eq.] from Germany's wetlands, as a result of land use and land-use changes, 1990 – 2013, by pools

6.7.2 Methodological issues (4.D)

6.7.2.1 Data sources

The production-quantity data for industrial peat extraction were taken from official German statistics (STATISTISCHES BUNDESAMT (FEDERAL STATISTICAL OFFICE), Fachserie 4, Reihe 3.1).

For further sources, cf. Chapters 6.3.1.1, 0 and 19.4.2.

6.7.2.2 Biomass

Water areas are free of vegetation cover, and thus the biomass carbon stocks are zero and are always reported in the CRF tables as "NO" (not occurring).

For the sub-category "wetlands (terrestrial)", changes in biomass carbon stocks, as a result of land-use changes, are calculated with the procedures and methods described in Chapter 6.1.2.3.

As a rule, terrestrial wetlands are covered with trees and shrubs (throughout a spectrum ranging from scattered bushes to actual forests), mosses and grasses, with mosses and grasses predominating. Accordingly, the inventory uses the following assumption relative to the area-related distribution of carbon stocks in biomass: 1/3 trees and shrubs and 2/3 mosses/grasses.

Since no biomass surveys of such lands have been carried out in Germany, the relevant values for woody grassland (Chapter 6.6.2.2.2) and grassland (in a strict sense) (Chapter 6.6.2.2.1) are used as approximations. **Therefore, the reporting methods are in keeping with those set forth in Chapter 6.6.2.2**.

The carbon stocks in terrestrial wetlands can then be calculated pursuant to Equation 41. The relevant results are shown in Table 315.

Equation 41:

$$\text{C stocks}_{\text{terr. wetlands}} = \text{C stocks}_{\text{woody grassland}} * 0.333 + \text{C stocks}_{\text{grassland (in a strict sense)}} * 0.667$$

Table 315: Area-related carbon stocks [Mg ha^{-1}] for biomass in Germany's terrestrial wetlands (95% **confidence interval**)

Terr. wetlands	**Carbon stocks [Mg C ha^{-1}]**		
	Bio$_{\text{above-ground}}$	**Bio$_{\text{below-ground}}$**	**Bio$_{\text{total}}$**
Terr. wetlands	3.80 (6.3 - 21.4)	5.04 (2.3 - 7.9)	18.85 (10.8 - 27.0)

The emission factors and pertinent uncertainties are presented in Table 317 (Chapter 7.5.5).

In keeping with the statements made in Chapter **6.6.2.2**, living biomass and dead organic matter are reported as "NO" (not occurring) in the relevant non-transfer categories of CRF table 4.D.1.

6.7.2.3 Mineral soils

It was assumed that no changes in the carbon stocks of mineral soils occurred in connection with land-use changes leading to water bodies ("NO" in CRF table 4.D.1).

For the sub-category "terrestrial wetlands", changes in mineral-soil carbon stocks, as a result of land-use changes, are calculated with the procedures and methods described in Chapter 6.1.2.3.

The emission factors and pertinent uncertainties are presented in Table 317 (Chapter 6.7.3).

6.7.2.4 Organic soils

Country-specific emission factors for organic soils in the sub-category terrestrial wetlands were determined in a national research project. As a result carbon-dioxide, nitrous-oxide and methane releases are also reported in this category (cf. Chapter 6.1.2.2).

6.7.2.4.1 Peat extraction

CO_2 emissions from peat extraction were calculated in conformance with the provisions of the 2006 IPCC Guidelines, using a Tier 2 method. The total emissions, comprising both on-site and off-site emissions, were calculated via the equations 7.2 - 7.5 of the 2006 IPCC Guidelines. In the sub-category peat extraction, CO_2 emissions (on-site (emissions and DOC), off-site), CH_4 emissions (emissions, and emissions from drainage ditches) and N_2O emissions (on-site) are reported. The manner in which the relevant emission factors are derived is described in Chapter 6.1.2.2. The estimates are based on the following activity data:

- Calculation of on-site emissions: The areas of the lands on which industrial peat extraction takes place were determined with the help of the B-DLM (cf. Chapter 6.3). Since the complete relevant data records were not added to the B-DLM until the year 2011, the peat-extraction area determined for 2011 is used for calculation of on-site emissions for all relevant years. The total extraction area has been a constant 19,857 ha.
- Calculation of off-site emissions: The quantities produced annually; these are taken from official German statistics (STATISTISCHES BUNDESAMT, Fachserie 4, Reihe 3.1).

Equation 7.3 (2006 IPCC Guidelines)

$$CO_2\text{-eq.}_{\text{peat extraction}} = CO_2\text{-eq.}_{\text{on-site}} + CO_2\text{-eq.}_{\text{off-site}}$$

CO_2-eq.$_{\text{peat extraction}}$: GHG emissions from peat extraction [Mg C-eq. a^{-1}]
CO_2-eq.$_{\text{on-site}}$: GHG emissions that occur on-site, during production [Mg C-eq. a^{-1}]
CO_2-eq.$_{\text{off-site}}$: GHG emissions that occur via extracted peat that is spread for horticultural purposes [Mg C-eq. a^{-1}]

In Germany, only peat from raised bogs is extracted. For this reason, Equation 7.4 (2006 IPCC Guidelines) was modified i the following manner:

$$CO_2\text{-eq.}_{\text{ on-site}} = A_{\text{peat, oligotrophic}} \text{ x } (\mathbf{EF_{peat,\ oligotrophic\_CO2}} + \mathbf{EF_{peat,\ oligotrophic\_N2O}} + \mathbf{EF_{peat,\ oligotrophic\_CH4}})$$

CO_2-eq $_{\text{on-site}}$: Emissions that occur during production, on-site [Mg C-eq. a^{-1}]
$A_{\text{peat, oligotrophic}}$: Peat-extraction area on raised bogs [ha]
$EF_{\text{peat, oligotrophic\_(CO2, N2O, CH4)}}$: Emission factor for peat extraction from raised bogs [0.2 Mg C-eq. ha^{-1} a^{-1} (IPCC Guidelines 2006, Table 7.4)]

On-site emissions were calculated with Equation 7.5 (2006 IPCC Guidelines):

$$CO_2\text{-}C_{off\text{-}site} = Vol_{peat\_dry} \times C_{fraction\ vol\_peat}$$

$CO_{2off\text{-}site}$: CO_2 emissions that occur via extracted peat that is spread for horticultural purposes [Mg CO_2-eq. a^{-1}]
Vol_{peat_dry}: Volume of air-dried peat [m^3]
$C_{fraction\ vol\_peat}$: Carbon fraction with respect to the volume of air-dried peat [0,2567 Mg CO_2-eq. m^{-3} (IPCC Guidelines 2006, Table 7.5)]

Table 316: Implied emission factors [Mg C ha^{-1} a^{-1}], **and emissions [Gg CO_2-eq.]** for peat extraction in Germany

Peat extraction Year	IEF [Mg CO_2-eq. ha^{-1} a^{-1}]	Emissions [Gg CO_2-eq.] on-site CO_2	on-site NO	on-site CH_4	off-site	Σ peat extraction
1990	108.79	117.2	7.9	5.6	2029.5	2160.2 ± 800.7
1991	105.75	117.2	7.9	5.6	1969.1	2099.8 ± 777
1992	116.60	117.2	7.9	5.6	2184.5	2315.2 ± 861.4
1993	115.82	117.2	7.9	5.6	2169.2	2299.9 ± 855.4
1994	123.61	117.2	7.9	5.6	2323.9	2454.6 ± 916.1
1995	117.57	117.2	7.9	5.6	2203.9	2334.6 ± 869
1996	114.54	117.2	7.9	5.6	2143.6	2274.3 ± 845.4
1997	114.03	117.2	7.9	5.6	2133.7	2264.4 ± 841.5
1998	123.01	117.2	7.9	5.6	2312	2442.7 ± 911.4
1999	126.77	117.2	7.9	5.6	2386.5	2517.2 ± 940.6
2000	128.26	117.2	7.9	5.6	2416.2	2546.9 ± 952.3
2001	127.62	117.2	7.9	5.6	2403.5	2534.2 ± 947.3
2002	111.93	117.2	7.9	5.6	2092	2222.7 ± 825.2
2003	113.22	117.2	7.9	5.6	2117.4	2248.1 ± 835.1
2004	115.20	117.2	7.9	5.6	2156.8	2287.5 ± 850.6
2005	116.35	117.2	7.9	5.6	2179.6	2310.3 ± 859.5
2006	116.84	117.2	7.9	5.6	2189.5	2320.2 ± 863.4
2007	120.98	117.2	7.9	5.6	2271.7	2402.4 ± 895.6
2008	113.46	117.2	7.9	5.6	2122.2	2252.9 ± 837
2009	114.69	117.2	7.9	5.6	2146.8	2277.5 ± 846.7
2010	106.87	117.2	7.9	5.6	1991.5	2122.2 ± 785.8
2011	108.84	117.2	7.9	5.6	2030.5	2161.2 ± 801.1
2012	112.64	117.2	7.9	5.6	2106	2236.7 ± 830.7
2013	109.42	117.2	7.9	5.6	2042	2172.7 ± 805.6

6.7.3 Uncertainties and time-series consistency (4.D)

The time series for activity data provided by the Federal Statistical Office for peat extraction are consistent and available for the entire period covered by the report. Pursuant to the Federal Statistical Office, the uncertainties for these activity data are "0", since the data have been obtained via an exhaustive survey entailing an obligation to provide information. Nonetheless, an uncertainty of 20 % is assumed, **in keeping with the IPCC Guidelines 2006.** That uncertainty is due primarily **to the uncertainty in conversion, for peat, of volume units to mass units.** The uncertainties listed in Table 317 and Table 304b, ranging up to 40 % for peat extraction, are the result of an uncertainties-propagation calculation. They are due especially to the large uncertainties in the IPCC default factors. The statements made in Chapter 6.6.3 and Chapter 6.7.3 also apply to the uncertainties for the emission factors for methane and nitrous oxide.

The activity data and area data have a normal distribution. Their uncertainties, depending on the area and sampling sizes involved, range from 2 % to 197 % (cf. Table 426 in Chapter 19.4.4). The total uncertainty for the area data in the wetlands category is 5.1 %. The wetlands pool's contributions to the total emissions and total uncertainty in the LULUCF sector are very small. Only the values relating to peat extraction are large enough to be noticeable (cf. Table 426 in Chapter 19.4.4).

Table 317: Emission factors and uncertainties [in % of location scale] used for calculation of GHG emissions from Germany's wetlands in 2013, broken down by pools and sub-categories

Wetlands$_{terrestrial}$ Land use$_{before}$	Land use$_{after}$	Emission factors	Boundaries lower	Boundaries upper	Waters Land use$_{after}$	Emission factors	Boundaries upper	Boundaries lower
Mineral soils CO_2-C[118]		**[Mg C ha^{-1} a^{-1}]**	**[%]**	**[%]**		**[Mg C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest land	Wetlands$_{terrestrial}$	0.64	24.0	28.5	Waters	No emissions		
Cropland	Wetlands$_{terrestrial}$	0.70	28.4	36.8	Waters	No emissions		
Grassland$_{i.s.s.}$	Wetlands$_{terrestrial}$	-0.17	31.8	47.4	Waters	No emissions		
Woody grassland	Wetlands$_{terrestrial}$	0.04	30.7	49.1	Waters	No emissions		
Settlements	Wetlands$_{terrestrial}$	0.77	31.6	47.6	Waters	No emissions		
Waters	Wetlands$_{terrestrial}$	0	43.9	52.5	Waters	No emissions		
Other land	Wetlands$_{terrestrial}$	0.92	31.5	49.8	Waters	No emissions		
Mineral soil, N_2O_{direct}[119]		[kg N_2O ha^{-1} a^{-1}]	[%]	[%]		[kg N_2O ha^{-1} a^{-1}]	[%]	[%]
Grassland$_{i.s.s.}$	Wetlands$_{terrestrial}$	0.213	91.7	211.5	Waters	No emissions		
Mineral soil, $N_2O_{indirect}$[119]		[kg N_2O ha^{-1} a^{-1}]	[%]	[%]		[kg N_2O ha^{-1} a^{-1}]	[%]	[%]
Grassland$_{i.s.s.}$	Wetlands$_{terrestrial}$	0.048	100.0	294.9	Waters	No emissions		
Organic soil[120]		[Mg CO_2-eq. ha^{-1} a^{-1}]	[%]	[%]		[Mg CO_2-eq. ha^{-1} a^{-1}]	[%]	[%]
Wetlands$_{terrestrisch}$, CO_2		8.69	59.9	46.1				
Wetlands$_{terrestrisch}$, N_2O		0.07	130.8	306.2				
Wetlands$_{terrestrisch}$, CH_4		0.18	78.9	669.9				
Peat extraction, CO_2		5.90	9.7	11.2				
Peat extraction, N_2O		0.40	46.9	258.9				
Peat extraction, CH_4		0.28	65.3	92.9				
Biomass[121]		[Mg C ha^{-1} a^{-1}]	[%]	[%]		[Mg C ha^{-1} a^{-1}]	[%]	[%]
Forest land	Wetlands$_{terrestrial}$	-35.81	22.6	22.8	Waters	-54.66	25.0	25.0
Cropland	Wetlands$_{terrestrial}$	11.32	30.6	31.1	Waters	-7.52	9.3	9.3
Grassland$_{i.s.s.}$	Wetlands$_{terrestrial}$	12.16	32.1	32.7	Waters	-6.69	25.4	25.4
Woody grassland	Wetlands$_{terrestrial}$	-24.32	33.9	34.5	Waters	-46.93	54.2	55.2
Wetlands$_{terrestrial}$	Wetlands$_{terrestrial}$	0	0	0	Waters	-18.85	42.6	43.3
Waters	Wetlands$_{terrestrial}$	18.85	42.6	43.3	Waters	0	0	0
Settlements	Wetlands$_{terrestrial}$	6.38	31.7	32.3	Waters	-12.46	47.1	47.9
Other land	Wetlands$_{terrestrial}$	18.85	42.6	43.3	Waters	0	0	0
Dead organic matter[121]		[Mg C ha^{-1} a^{-1}]	[%]	[%]		[Mg C ha^{-1} a^{-1}]	[%]	[%]
Forest land	Wetlands$_{terrestrial}$	-20.70	5.9	5.9	Waters	-20.70	5.9	5.9

Positive: sink; negative: source

The calculations are spatially and chronologically consistent and complete for the entire report period, 1990 – 2013.

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118 Calculation covers a 20-year period; stock change: positive ≙ sink; negative ≙ source

119 Calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink

120 Annual calculation; emission: positive ≙ source; negative ≙ sink

121 Calculation only for first year of land-use change, stock change: positive ≙ sink; negative ≙ source

Table 318: Uncertainties for emission factors [2.5 and 97.5 percentile, in % of location scale] for emissions from organic soils, for wetlands and peat extraction, 2013

Land use	Greenhouse gas	Emission factor	Boundaries	
			lower	upper
Organic soil[122]		[Mg CO_2-eq. ha^{-1} a^{-1}]	%	%
Wetlands$_{terrestrial}$	CO_2	8.69	59.9	46.1
Wetlands$_{terrestrial}$	N_2O	0.07	130.8	306.2
Wetlands$_{terrestrial}$	CH_4	0.18	78.9	669.9
Peat extraction	CO_2	5.90	9.7	11.2
Peat extraction	N_2O	0.40	46.9	258.9
Peat extraction	CH_4	0.28	65.3	92.9

6.7.4 Category-specific QA/QC and verification (4.D)

With regard to quality control and quality assurance, we refer to Chapter 6.1.3.

The data sources used in preparation of this inventory fulfill the review criteria of the QSE manual for data sources (QSE-Handbuch für Datenquellen). Quality assurance for input data (ATKIS®, BÜK, official statistics) is the responsibility of the relevant data administrators (cf. the pertinent documentation in the inventory description).

The emissions-calculation results as presented in the present report cannot be compared with other relevant data sources for Germany, since no such other data sources exist that meet applicable requirements, i.e. provide complete coverage, are comprehensive and are independent of the methods and data sources described in the present report. A comparison of Germany's implied emission factors, in the wetlands category, with those of European neighbouring countries shows that the IEF hardly lend themselves to comparison. This is due to differences between the pertinent combinations of soil types. In the non-transfer ("remaining") category, for example, Germany has the largest emission factor, because Germany's wetlands category includes peat extraction and related off-site emissions. National definitions play an especially strong role in the wetlands category. Since the applicable national circumstances differ widely from country to country, the various implied emission factors span a wide range overall. In the transfer category, Germany lists the soils as a small carbon source and the biomass as a carbon sink. The changes in the IEF, with respect to the previous year, are due mainly to differences in the previous uses on the conversion areas (Table 305). For example, the reason for the difference in the biomass is that 400 ha of forest land were transferred to wetlands / waters in 2012, while no forest land was transferred to those categories in 2013. This factor also has impacts on the IEF for dead organic matter, as can be seen by comparing the previous year's value with the current value.

[122] Annual calculation; emission: positive ≙ source; negative ≙ sink

Table 319: Comparison of implied emission factors (IEF) for various wetlands pools, for Germany and for neighbouring countries in Europe, for the year 2012 (exception: Germany, NIR 2015: the 2013 figure is used, for comparison)

Implied emission factors (IEF), wetlands, NIR 2014	Wetlands remaining wetlands	Land-use changes leading to wetlands		
	Soils	Soils	Biomass	Dead org. matter
		Mg C ha^{-1}		
Austria	NE	NO	-0.69	-0.16
Belgium	NO	1.16	NO	NO
Denmark	-0.07	0.38	0.00	NA,NE,NO
France	NO	2.51	-0.42	-0.04
UK	-0.57	NO	NE,NO	NO
Netherlands	NO	0.64	-1.06	-0.17
Poland	NA	NA,NO	-1.20	NA,NO
Czech Republic	NO	NA,NO	-0.57	-0.01
Switzerland	0.00	-3.44	-4.07	-0.68
Germany, NIR 2014	-0.99	0.02	-0.40	-0.85
Germany, NIR 2015	**-1.13**	**-0.05**	**0.10**	**0.00**

Positive: sink; negative: source

6.7.5 *Category-specific recalculations (4.D)*

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

Because the 2006 IPCC Guidelines (IPCC 2006) have been implemented in this year's submission, a complete recalculation of the inventory was carried out, on the basis of those Guidelines. It covered all category-specific time series for the entire reporting period, 1990 – 2013.

6.7.6 *Category-specific planned improvements (4.D)*

No further improvements, in addition to those previously announced, are planned. Information about the implementation status of planned improvements in the LULUCF sector is presented in Chapter 6.1.4.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

6.8 Settlements (4.E)

6.8.1 Category description (4.E)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T/2	**4.E Settlements**		**CO2**	**2.548,9**	**(0,21%)**	**3.577,8**	**(0,38%)**	**40,4%**
-/-	4.E Settlements		N2O	156,7	(0,01%)	183,6	(0,02%)	17,1%
-/-	4.E Settlements		CH4	38,6	(0,00%)	38,9	(0,00%)	0,6%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	RS/NS	CS
N_2O	Tier 2	RS/NS	CS
CH_4	Tier 2	RS/NS	CS

The category *Settlements* (4.E) is a key category for CO_2 emissions in terms of emissions level and trend and of Tier 2 analysis.

Reporting for the land-use category "settlements" has to cover CO_2 emissions / removals in the pools "soil", "biomass" and "dead organic matter" on land designated for settlement and transport uses. Precise definitions and category allocations are presented in Chapter 6.2. The results of the estimation of relevant greenhouse-gas emissions are presented in Table 320 and in Figure 71 and Figure 72.

Table 320: CO_2, N_2O and CH_4 emissions [Gg CO_2-eq.] from Germany's settlements, 2013. The table includes both the relevant sums and the upper and lower bounds of the 95 % confidence interval.

Category	GHG	Emissions, settlements, 2013 [Gg CO_2-eq.] Emission	2.5 perc.	97.5 perc.	[%] 2.5 perc.	97.5 perc.
Settlements$_{total}$		**3,822.3**	**3,358.1**	**4,290.1**	**12.1**	**12.2**
Mineral soils	CO_2	979.1	729.4	1,433.0	25.5	46.4
	N_2O_{direct}	**98.1**	72.1	168.1	73.5	171.4
	$N_2O_{indirect}$	**22.1**	0	52.4	100	237.3
Organic soil	CO_2	1,834.0	1,257.6	2,146.5	31.4	17.0
	N_2O	85.5	37.2	193.6	56.4	126.6
	CH_4	38.9	28.5	96.0	26.6	146.9
Biomass	CO_2	185.2	156.6	218.4	15.4	17.9
Litter / dead wood	CO_2	579.5	545.1	681.8	5.9	17.7

In 2013, the CO_2 emissions from Germany's settlement and transport areas, as a result of land use and land-use changes, amounted to 3,822 Gg CO_2 (Table 3XX). The majority of these emissions (51 %) was caused by drainage of organic soils. At the same time, emissions from mineral soils, accounting for a share of 29 %, also contributed significantly to the emissions total. These emissions are caused primarily by land-use changes from Grassland (in a strict sense) (32 %) and Forest Land (48 %) to Settlements (Figure 71). As a result of the changes, the emissions, which were originally negative (sink) with the biomass, are now positive, i.e. now function as a source (Figure 72). In addition, relatively high emissions occurred from dead organic matter (15 %) and mineral soils (in this category, especially due to conversions from grassland (i.s.s.) to settlements).

With respect to the base year, a net emissions increase of 1,061.9 Gg CO_2 ≙ 38.5 % occurred in 2013 (cf. Figure 71 and Figure 72). The trend is clearly directed, and it is being driven primarily by conversion of forest land and grassland areas for settlement purposes. As a result of deforestation, emissions from the settlements sector increased by 1,271 Gg CO_2 ≙ 222.2 % in 2013, with respect to 1990. Biomass, accounting for 70 %, was the main source, followed by dead organic matter (17%) and mineral soils (13 %). While the last of these was still a sink in 1990, it now functions as a source. An emissions decrease with respect to 1990 occurred in the "remaining" category (-42 %). It is due to the decrease in emissions from organic soils as a result of area migration (-13 kha ≙ -42 %). The emissions from the transfer category Cropland also decreased (-14 %), although the relevant area has increased since 1990 (+177 kha ≙ 49 %). The higher emissions from soils are completely offset by the sink function of biomass, however.

The shapes of the time-series plots – especially the noticeable changes they show – are due primarily to the changes in area data that have occurred as of the relevant explicitly defined survey dates (cf. Chapter 6.3.3, Table 275).

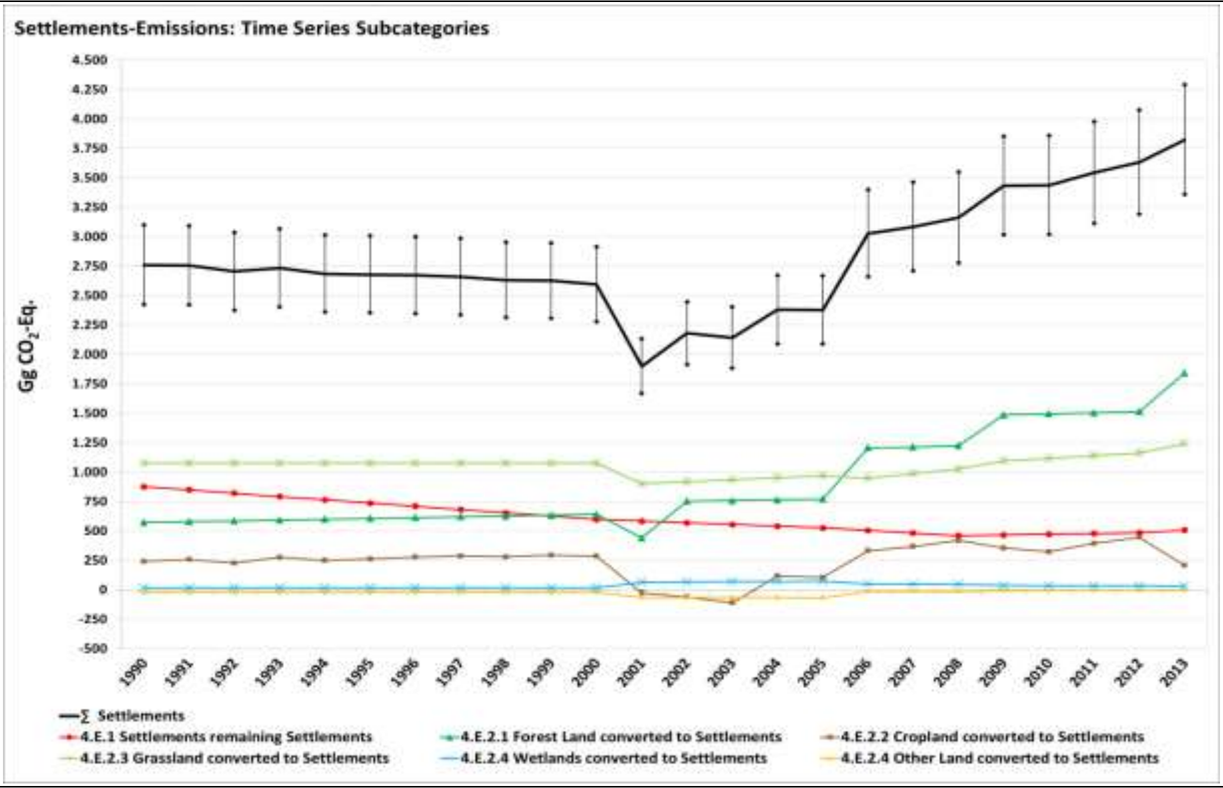

Figure 71: CO_2 emissions [Gg CO_2-eqs.] from Germany's settlements, as a result of land use and land-use changes, 1990 – 2013, by sub-categories

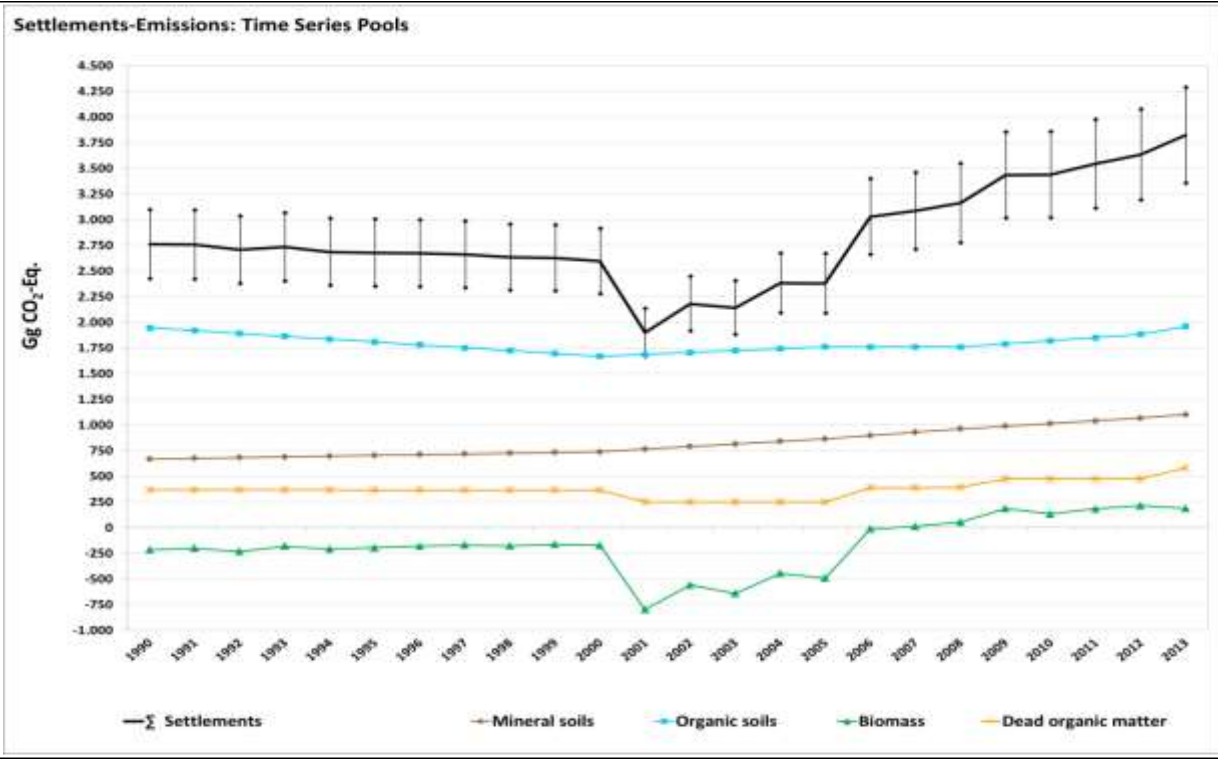

Figure 72: CO_2 emissions [Gg CO_2-eqs.] from Germany's settlements, as a result of land use and land-use changes, 1990 – 2013, by pools

6.8.2 Methodological issues (4.E)

In the case of settlements remaining settlements, it is assumed that no carbon-stock changes occur in mineral soils (cf. Chapter 6.5.2.2 and Chapter 6.6.2.3) and biomass (cf. Chapter 6.6.2.2). It has also been assumed that organic soils in settlements have been drained.

All five carbon pools are reported in connection with land-use changes leading to settlements (cf. also Chapter 6.5.2).

6.8.2.1 Data sources

Further information about the data sources is provided in Chapter 6.3.1.1.

6.8.2.2 Biomass

Settlement and transport areas tend to have significant portions of unsealed land that is covered with vegetation. Representative-sample studies of the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR), an institute sited within the Federal Office for Building and Regional Planning (BBR), have shown that built-over and sealed areas account for 40 – 50 % of designated settlement and transport areas (EINIG et al. 2009). In the German inventory, areas covered with vegetation are assumed to account for an average of 50 % of settlement areas.

No data have been collected specifically with regard to biomass and carbon stocks on such areas within Germany's settlement and transport areas. The following assumption is used as a way of compensating for that lack: half of all areas covered with vegetation consist of woods (trees and bushes) and half consist of green areas comparable to "grassland (in a strict sense)". That assumption is approximately in keeping with the corresponding basic figures used in Switzerland. Via remote sensing, it was determined there that trees and bushes account for 47.4 % of plant cover, with trees accounting for 32.1 % and bushes accounting for 15.3 % (FOEN 2010). Since settlement and transport areas tend to have an enormous variety of trees and shrubs – including small-garden shrubs, many different types of hedges and large trees along roads and in forests – the tree/shrub biomass in this land-use category was determined on the basis of the country-specific value for woody grassland. **For this reason, no carbon-stock changes in woody-plant mass are reported in the non-transfer category of settlement areas** (NO in CRF table 4.E.1 for living biomass and dead organic matter)**. In addition, the calculation rules as described in Chapter 6.6.2.2 apply.** The carbon stocks in settlement areas can then be calculated pursuant to Equation 42. The relevant results are shown in Table 321.

Equation 42:

$$C\ stocks_{settlements} = (C\ stocks_{woody\ grassland} * 0.5 + C\ stocks_{grassland\ (in\ a\ strict\ sense)} * 0.5) * 0.5$$

Table 321: Area-related carbon stocks [Mg ha^{-1}] in biomass on settlement areas (**95% confidence interval**)

Settlements	Carbon stocks [Mg C ha^{-1}]		
	$Bio_{above-ground}$	$Bio_{below-ground}$	Bio_{total}
Settlements	9.26 (3.71 - 14.91)	3.20 (1.33 - 5.15)	12.46 (6.60 - 18.44)

6.8.2.3 Mineral soils

Further information about mineral soils is provided in Chapters 6.1.2.1 and 19.4.2.

6.8.2.4 Organic soils

No data have been collected specifically with regard to drainage of organic soils in settlements. In compensation for that gap, it is assumed that such soils are drained in the same manner that cultivated grassland is drained, and thus the relevant emission factors for such drainage are used (Chapter 6.6.2.4).

In cases involving land-use changes leading to settlements, the relevant value for settlements remaining settlements is used from the outset.

6.8.3 Uncertainties and time-series consistency (4.E)

The consistency of the time series is assured with regard to the activity data and emission factors.

The emission factors and uncertainties for the land-use category Settlements are listed in Table 322and Table 323. In general, the uncertainties show a log-normal distribution, with the exception of those for CO_2 from organic soils, which have a right-skewed distribution. The statements made in Chapter 6.6.3 apply to the major uncertainties relative to direct and indirect nitrogen emissions. The uncertainties, as shown in Table 426 in Chapter 19.4.4, and depending on the area size concerned, range from 2.5% to 71 %. The total uncertainty for the activity data in the settlements category is 2.6 %. The emissions' contribution to the uncertainty of the inventory as a whole is low in the categories of emissions from organic soils, emissions from biomass and emissions from mineral soils.

Table 322: Uncertainties of emission factors [in % of location scale] used for calculation of GHG emissions from settlement and transport areas in 2013, broken down by pools and sub-categories

Settlements **Land use before** **Mineral soils CO_2-C**[123]	**Area** **Land use after**	**Emission factor** **[Mg C ha^{-1} a^{-1}]**	**Boundaries** **upper** **[%]**	 **lower** **[%]**
Forest land	Settlements	-0.097	22.3	40.9
Cropland	Settlements	-0.07	27.9	49.2
Grassland (in a strict sense)	Settlements	-0.94	32.6	57.5
Woody grassland	Settlements	-0.73	31.2	59.7
Terr. wetlands	Settlements	-0.77	31.6	47.6
Waters	Settlements	0.00	45.1	85.0
Other land	Settlements	0.15	31.7	62.8
Mineral soil, N_2O_{direct}[124]		[kg N_2O ha^{-1} a^{-1}]	[%]	[%]
Forest land	Settlements	0.078	73.5	204.1
Cropland	Settlements	0.087	90.4	211.9
Grassland (in a strict sense)	Settlements	1.162	92.0	214.6
Woody grassland	Settlements	0.932	96.2	222.3
Terr. wetlands	Settlements	0.780	91.6	211.6
Mineral soil, $N_2O_{indirect}$[125]		[kg N_2O ha^{-1} a^{-1}]	[%]	[%]
Forest land	Settlements	0.018	100.0	289.7
Cropland	Settlements	0.019	100.0	295.2
Grassland (in a strict sense)	Settlements	0.261	100.0	296.7
Woody grassland	Settlements	0.210	100.0	297.1
Terr. wetlands	Settlements	0.175	100.0	294.9
Organic soil[126]		**[Mg C ha* a^{-1}]**	**[%]**	**[%]**
Settlements	CO_2	27.1	55.4	28.4
Settlements	N_2O	1.3	99.4	222.7
Settlements	CH_4	0.6	46.9	258.6
Biomass[127]		**[Mg C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest land	Settlements	-42.20	22.5	22.6
Cropland	Settlements	4.94	29.6	30.1
Grassland (in a strict sense)	Settlements	5.78	31.9	32.4
Woody grassland	Settlements	-30.70	43.4	44.2
Terr. wetlands	Settlements	-6.38	31.7	32.3
Waters	Settlements	12.46	47.1	47.9
Other land	Settlements	12.46	47.1	47.9
Dead organic matter[128]		**[Mg C ha^{-1} a^{-1}]**	**[%]**	**[%]**
Forest land	Settlements	-20.70	5.9	

Table 323: Uncertainties for emission factors [2.5 and 97.5 percentile, in % of location scale] for emissions from organic soils under settlements, 2013

Land use	**Greenhouse gas** **Organic soil**[129]	**Emission factor** **[Mg CO_2-eq. ha^{-1} a^{-1}]**	**Boundaries** **lower** **[%]**	 **upper** **[%]**
Settlements	CO_2	27.1	55.4	28.4
Settlements	N_2O	1.3	99.4	222.7
Settlements	CH_4	0.6	46.9	258.6

6.8.4 Category-specific quality assurance / control and verification (4.E)

With regard to quality control and quality assurance, we refer to Chapter 6.1.3.

The data sources used in preparation of this inventory fulfill the review criteria of the QSE manual for data sources (QSE-Handbuch für Datenquellen). Internally, data processing is checked pursuant to Thünen-Institut (2012). Quality assurance for input data (ATKIS®, BÜK,

123 Calculation covers a 20-year period; stock change: positive ≙ sink; negative ≙ source

124 Calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink

125 Calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink

126 Annual calculation; emission: positive ≙ source; negative ≙ sink

127 Calculation only for first year of land-use change, stock change: positive ≙ sink; negative ≙ source

128 Calculation only for first year of land-use change, stock change: positive ≙ sink; negative ≙ source

129 Annual calculation; emission: positive ≙ source; negative ≙ sink

official statistics) is the responsibility of the relevant data administrators (cf. the pertinent documentation in the inventory description).

The emissions-calculation results as presented in the present report cannot be compared with other relevant data sources for Germany, since no such other data sources exist that meet applicable requirements, i.e. provide complete coverage, are comprehensive and are independent of the methods and data sources described in the present report. Table 324 compares the average emission factors for the Settlements category with those of European neighbouring countries.

Only Germany, Switzerland and the UK report CO_2 emissions from drained organic soils in settlement areas. The implied emission factors are referenced to the total settlement land area. Consequently, they also reflect organic soils' share of that total area. In the German inventory, other C pools are calculated only in connection with land-use changes leading to settlements. All such changes are sources (this is also the case for nearly all listed countries), and this status is most pronounced in the area of soils. While other immediate neighbours (such as France, Switzerland and Belgium) show a considerably higher source function for mineral soils, Austria's value is of about the same size as Germany's, and thus also lies at the lower end of the spectrum. The IEF for biomass lie within the middle of the range for European neighbouring countries. The source function resulting in the German inventory is due to the large biomass losses occurring as a result of deforestation (cf. Chapter 6.8.1). The implied emission factors for the three pools depend strongly on the original uses involved in each case, and thus the wide range seen throughout European countries cannot be interpreted without knowledge of such uses.

Table 324: Comparison of implied emission factors (IEF) for various settlements pools, for Germany and for neighbouring countries in Europe, for the year 2012 (exception: Germany, NIR 2015: the 2013 figure is used, for comparison)

Implied emission factors (IEF), settlements, NIR 2014	**Settlements remaining settlements**	**Land-use changes leading to settlements**		
	Organic soils	**soils**	**Biomass**	**Dead org. matter**
		Mg C ha^{-1}		
Austria	NE	-0.46	0.32	-0.03
Belgium	NO	-1.06	-0.20	-0.02
Denmark	NA,NO	-0.30	-0.48	0.00
France	NO	-1.31	-0.66	-0.08
UK	-0.70	-3.10	-0.04	-0.01
Netherlands	NO	-0.10	-1.16	-0.20
Poland	NA	-0.28	-0.41	-0.01
Czech Republic	NO	NA,NO	-0.39	-0.01
Switzerland	-0.02	-1.20	-0.51	-0.06
Germany, NIR 2014	-0.15	-0.55	-0.03	-0.12
Germany, NIR 2015	**-0.04**	**-0.69**	**-0.05**	**-0.17**

Positive: sink; negative: source

6.8.5 *Category-specific recalculations (4.E)*

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

Because the 2006 IPCC Guidelines (IPCC 2006) have been implemented in this year's submission, a complete recalculation of the inventory was carried out, on the basis of those Guidelines. It covered all category-specific time series for the entire reporting period, 1990 – 2013.

6.8.6 Category-specific planned improvements (4.E)

No further improvements, in addition to those previously announced, are planned. Information about the implementation status of planned improvements in the LULUCF sector is presented in Chapter 6.1.4.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

6.9 Other land (4.F)

6.9.1 Category description (4.F)

Since, by definition, the areas in the category "Other Land" consist of areas that are not cultivated, the sizes of such areas are included solely for the purpose of completing the area matrix. Emissions within the meaning of IPCC-LULUCF cannot occur on such areas. Therefore, no such emissions are reported. For this reason, "NO" is entered in all relevant spaces in CRF table 4.F, with the exception of the space for the area of the non-transfer category.

6.9.2 Methodological issues (4.F)

In emissions calculation, Other Land areas are taken into account solely as a "before" category in connection with land-use changes leading to other categories. No conversions back to "Other Land" take place, since, by definition, once land has been managed it can no longer be returned to an "unmanaged land" land-use category.

The carbon stocks in biomass, dead wood and dead organic matter of Other Land are "zero".

The carbon stocks in mineral soils of Other Land are listed in Chapters 6.1.2.1 and 19.4.2.

Organic soils in Other Land are not drained.

6.9.3 Uncertainties and time-series consistency (4.F)

The uncertainties for the emission factors and the activity data were determined in accordance with the 2006 IPCC Guidelines (IPCC 2006). Additional relevant information is provided in Chapter 19.4.4.

The time series is complete and consistent.

6.9.4 Category-specific quality assurance / control and verification (4.F)

With regard to quality control and quality assurance, we refer to Chapter 6.1.3.

6.9.5 Category-specific recalculations (4.F)

Not applicable, since no greenhouse-gas sources and sinks are reported in this category.

6.9.6 Category-specific planned improvements (4.F)

Not applicable, since no greenhouse-gas sources and sinks are reported in this category.

6.10 Harvested wood products (4.G)

6.10.1 Category description (4.G)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T/2	4.G Harvested wood products		CO2	-1.360,0	(0,11%)	-2.588,0	(0,28%)	90,3%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS/Tier 2	IS/NS	D

The category Harvested Wood Products (4.G) is a key category for CO_2 emissions, in terms of emissions level and trend and of Tier 2 analysis.

Via their use as materials, harvested wood products (HWP) lengthen the time for which part of the carbon lost from forests, via logging, remains bound.

The contribution of HWP in the land-use sector in Germany, in terms of greenhouse emissions by sources and removals by sinks, was estimated with the WoodCarbonMonitor model, via an approach based on production data for wood products. The estimate covers all wood products that are produced in Germany, that consist of wood that originates from trees harvested in Germany and that are used for their material (not energy) value.

For reasons of consistency, the calculation was carried out in keeping with the rules in Chapter 2.8 of the 2013 IPCC KP Supplement (IPCC 2014). Pursuant to footnote 12 in table sheet 4.G s1 of the Common Reporting Format in Annex II of Decision 24/CP.19 (UNFCCC 2014), IPCC Guidelines other than the 2006 IPCC Guidelines may be used for the chosen approach (approach B) if they are in keeping with that approach. The system boundaries described in the rules of the *2013 IPCC KP Supplement*, for estimation of the contribution of HWP, are consistent with the system boundaries of the approach referred to in Table 12.1 of the *2006 IPCC Guidelines* with variable 2A.

To enhance transparency, and pursuant to reporting table 4.G s1, a distinction is made between HWP that are produced and domestically consumed in Germany and wood products that are produced and exported. The carbon stored in wood in solid waste disposal sites is not taken into account.

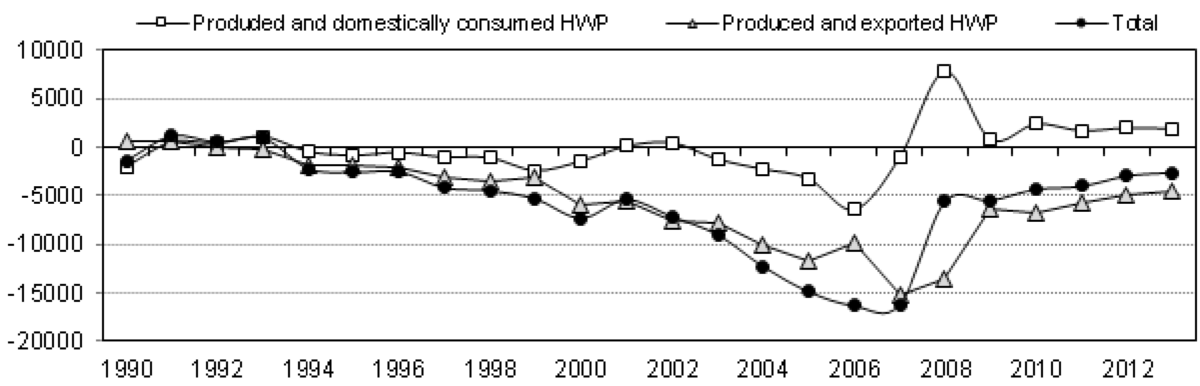

Figure 73: CO_2 emissions and removals in HWP (in kt CO_2)

6.10.2 Methodological issues (4.G)

6.10.2.1 Activity data

Figure 74 shows the development of production quantities in the semi-finished-product categories sawnwood and wood-based panels, broken down by the wood quantities remaining in Germany (production, less exports) and the quantities exported (exports), since 1990. The figure is based on data of the Food and Agriculture Organization of the United Nations (FAO) (FAO 2014). These time series are in keeping with the data proposed in the *2006 IPCC Guidelines* for estimation of the contribution of HWP using a Tier 1 estimation method (Chapter 12.2.1, IPCC 2006: 12.9).

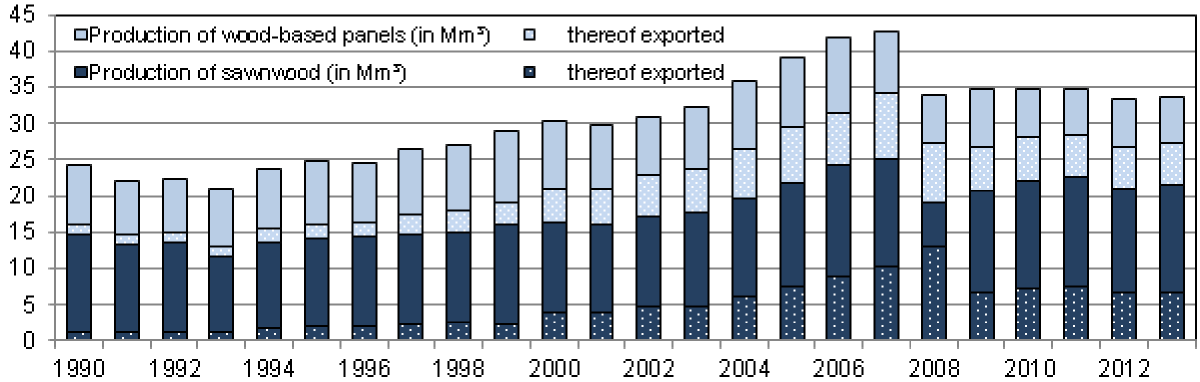

Figure 74: Sawnwood and wood-based panels produced in Germany (FAO 2014)

In line with the IPCC Guidelines, in a first step, the feedstock fraction in HWP from domestically harvested wood was calculated, and a domestic feedstock factor $f_{DP}(i)$ was determined. For the semi-finished-product categories sawnwood and wood-based panels, this factor is based on the FAO data on the feedstock category *industrial roundwood*. For calculation of the domestically harvested fraction in the product category paper and paperboard, the use of recovered paper in paper production was taken into account, in addition to the wood-pulp feedstock category as proposed in the IPCC 2013 KP Supplement, since the recovered-paper-utilization rate (p) in Germany has been growing continually in recent years and now exceeds 70% (Figure 75). Along with the factors for industrial roundwood (f_{IRW}) and wood pulp (f_{PULP}), which were calculated using Equations 2.8.1 and 2.8.2 of the *IPCC 2013 KP Supplement* (IPCC 2014: 2.115), an additional factor for *recovered paper* was determined, using the same approach, with the help of the FAO data (f_{RecP}) (Figure 76). That factor was used in calculation of the product fractions originating in the domestic harvest via Equation 2.8.4 of the IPCC 2013 KP Supplement (IPCC 2014: 2.118), for the category "paper and paperboard", with $f_{DP}(i)$ = $((f_{IRW}(i) \bullet (1-p) \bullet f_{PULP}(i)) + p \bullet f_{RecP}(i))$.

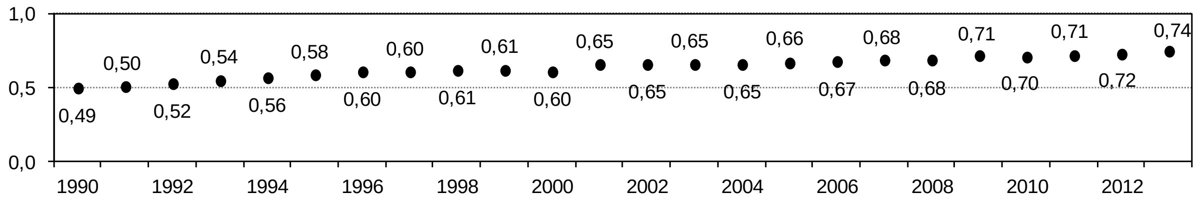

Figure 75: Utilization rate p for recovered paper in the production of paper and paperboard (Verband Deutscher Papierfabriken e.V. 2014)

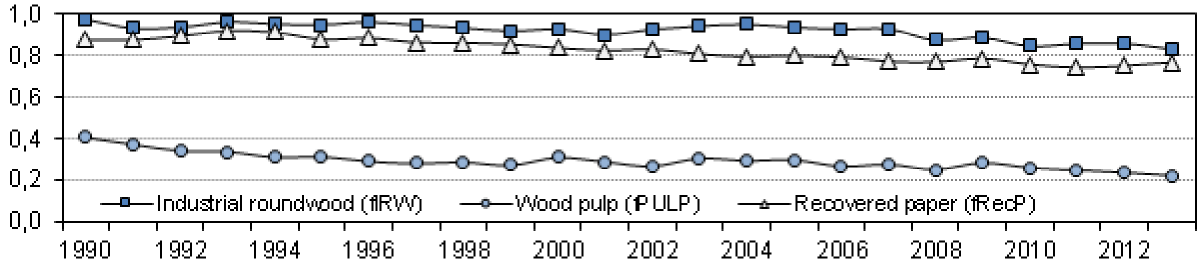

Figure 76: Development of the domestic feedstock factors fDP(i) for the raw-material categories considered (FAO 2014)

In a second step (Chapter 2.8.1.2, IPCC 2014), the carbon contained in the relevant products was allocated to the respective land-use classes from which the raw material originates. For Germany, the wood harvest can be broken down into wood harvested on forest land remaining forest land (category 5A1, Chapter 6.2.1), and wood harvested as a result of land-use changes from forest land to other categories (Table 325). In keeping with IPCC requirements, HWP from conversion of forest land are taken into account on the basis of instantaneous oxidation (cf. Chapter 2.8.3, IPCC 2014). Consequently, the annual wood harvest fractions from managed forest areas $f_{FM}(i)$ can be calculated on the basis of the inventory information available for Germany and of Equation 2.8.3 (IPCC 2014: 2.116).

Table 325: Annual wood-harvest fraction from forest land remaining forest land

Time period	$f_{FM}(i)$
1990 – 2002	0.98989
2003 – 2007	0.99202
2008 – 2012	0.98881

6.10.2.2 Emission factors

The carbon outflows from the carbon stock are calculated with the default values listed in Table 2.8.2 of the *IPCC 2013 KP Supplement*. Those values are based on the values mentioned in Table 3a.1.3 of the *IPCC GPG-LULUCF*.

6.10.2.3 Calculation method used

To calculate the contribution of HWP used, as material, to the delayed release of CO_2 emissions, on the basis of carbon-pool changes, Germany uses the exponential decay function described in the IPCC Guidelines, in combination with the product categories described in Table 2.8.1 of the *IPCC 2013 KP Supplement*. This conforms to the default method described in the *2006 IPCC Guidelines* (Equation12.1, IPCC 2006: 12.11) and to the Tier 2 default method in the *IPCC 2013 KP Supplement* (Equation 2.8.5). For the carbon conversion calculation, the factors listed in Table 2.8.1 are used for the product categories "wood-based panels" and "paper and paperboard". The carbon quantities in the product categories "non-coniferous and coniferous sawnwood" are calculated by means of the factors as described in Rüter 2011 (cf. also UNFCCC 2011), in order to take account of the wood species typically used in Germany for the production of sawnwood.

Time series, of adequate quality, for HWP and the relevant feedstock categories are available only for the period since German reunification in 1990. For that reason, and in order to reduce the uncertainties associated with the activity data, the initial value of the carbon stocks in HWP is calculated on the basis of Equation 2.8.6 (IPCC 2014), with $C(t_0)$ = 1990.

6.10.2.4 Uncertainties and time-series consistency (4.G)

The time series for HWP activity data from the FAO database are consistent and are available for the entire period covered by the report. Pursuant to the information provided in the relevant chapter of the IPCC KP Supplement (2014), the uncertainties for these time series amount to -25/+5 % (cf. also Chapter 11.3.1.5).

6.10.3 Category-specific quality assurance / control and verification (4.G)

With regard to quality control and quality assurance, we refer to Chapter 6.1.3.

6.10.4 Category-specific recalculations (4.G)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

6.10.5 Category-specific planned improvements (4.G)

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

6.11 Other areas (4.H)

Normally, no emissions are reported under 4.H (NO).

However, due to structural changes in reporting, indirect N_2O emissions from losses of organic soil substance (Table 4(IV), Nitrogen leaching and run-off) are reported here in the trend tables and category analysis (cf. the detailed description in Chapter 6.4.2.7.5).

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/-	4.H Other		N_2O	111.1	(0.01%)	105.3	(0.01%)	-5.2%

The N_2O emissions reported, for the reasons mentioned, under *4.H Other areas* are not a key category.

Furthermore, as a result of the structural problems that occurred in the *CRF-Reporter* report database, the CH_4 and N_2O emissions from 4.E (Settlements; cf. NIR chapter 6.8.1) and the N_2O emissions from 4.C (Grassland; cf. NIR chapter 6.6.1) also have to be reported under 4.H (Other).

7 WASTE AND WASTE WATER (CRF SECTOR 5)

7.1 Overview (CRF Sector 5)

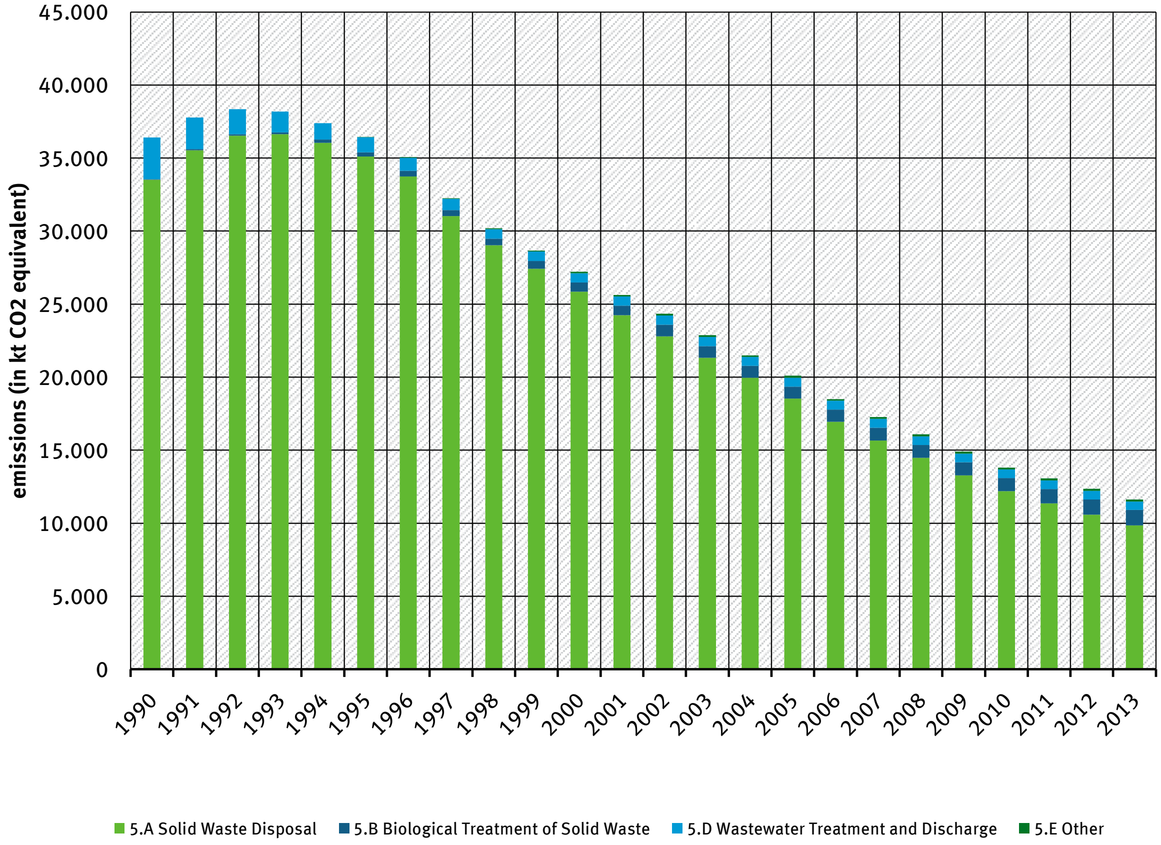

Figure 77: Overview of greenhouse-gas emissions in CRF Sector 6

7.2 Solid waste disposal on land (5.A)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
L/T/2	5.A Solid Waste Disposal on Land	Managed Waste Disposal on Land	CH4	33.525,0	(2,75%)	9.850,0	(1,05%)	-70,6%

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	NS	CS/D

The category *Solid waste disposal on land* is a key category of CH_4 emissions in terms of emissions level and trend and pursuant to Tier 2 analysis.

Only managed disposal in landfills (5.A.1) is relevant for purposes of German emissions reporting under CRF 6.A. "Wild" or illegal dumping of solid waste (CRF 5.A.2) is prohibited by law in Germany.

Emissions from composting and from mechanical biological waste treatment (MBT) have been reported since 2004, in keeping with the growing importance of such other methods for treating biodegradable waste fractions. With the conversion of the CRF tables as of the 2013 report year, these emissions are reported under category 5.B Biological waste treatment.

In the Central System of Emissions (CSE), the categories assigned to category 5.A Solid waste disposal on land include landfilled residential waste, biologically degradable waste from industry and sewage sludge.

7.2.1 Managed disposal in landfills – landfilling of settlement waste (5.A.1)

7.2.1.1 Category description (5.A.1)

In the period since 1990 (and previously, to some extent), a number of legal provisions have been issued pertaining to Germany's waste-management sector, and a number of relevant organisational measures have been initiated. These moves have had a strong impact on trends in emissions from waste-landfilling. Relevant developments have included intensified collection of biodegradable waste from households and the commercial sector, intensified collection of other recyclable materials, such as glass, paper/cardboard, metals and plastics; separate collection of packaging; and recycling of packaging. In addition, incineration of settlement waste has been expanded, and mechanical biological treatment of residual waste has been introduced. As a result of such measures, amounts of landfilled settlement waste decreased very sharply from 1990 to 2006, and they have been stabilising at a low level since 2006 (cf. Figure 78). As the figure shows, over half of settlement waste produced in Germany today is collected separately and gleaned for recyclable materials (separate collection of recyclable materials and biodegradable waste). Official statistical data (*STATISTISCHES BUNDESAMT* (Federal Statistical Office) Fachserie 19, Reihe 1 Abfallentsorgung 2012 ("Waste management, 2012") of 29 July 2014) are available for the period until 2012. The activity data for a given year (such as 2013) are obtained, initially, by carrying the relevant data from the previous year (such as 2012) forward, in unchanged form. In the following year (2014), when the actual activity data for the given year (2013) become available, they replace the data that were carried forward. With regard to emissions from landfills, this procedure has only a very small impact on the total emissions in the relevant current report year, since those emissions are determined predominantly by the waste that has been landfilled in the past.

In 2004, about 330 landfills for settlement waste were in operation in the Federal Republic of Germany. By that year, strict legal regulations were already in place that require such landfills to have equipment for collecting and treating landfill gas. Those regulations have extensively reduced methane emissions from such facilities. In June 2005, in keeping with new, stricter requirements under the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements (Abfallablagerungsverordnung) and the Landfill Ordinance (Deponieverordnung), over half of all landfills were closed. As a result, only about 150 landfills for settlement waste are now still in operation. Pursuant to regulations in force since June 2005, landfilling of biodegradable waste is no longer permitted. Consequently, since June 2005 it has no longer been possible to landfill waste with the potential for significant methane formation. For conformance with pertinent requirements, settlement waste and other biodegradable waste must be pre-treated via thermal or mechanical biological processes. In waste landfilled after 2006, just a few waste components, with very small methane-formation potential (such as residues from treatment in MBT facilities; small wood fractions in construction rubble) have contributed to landfill-gas formation. As landfill-gas formation in older landfills drops off, methane emissions from landfills will again decrease extensively and will then, in the long term, stabilise at a very low level.

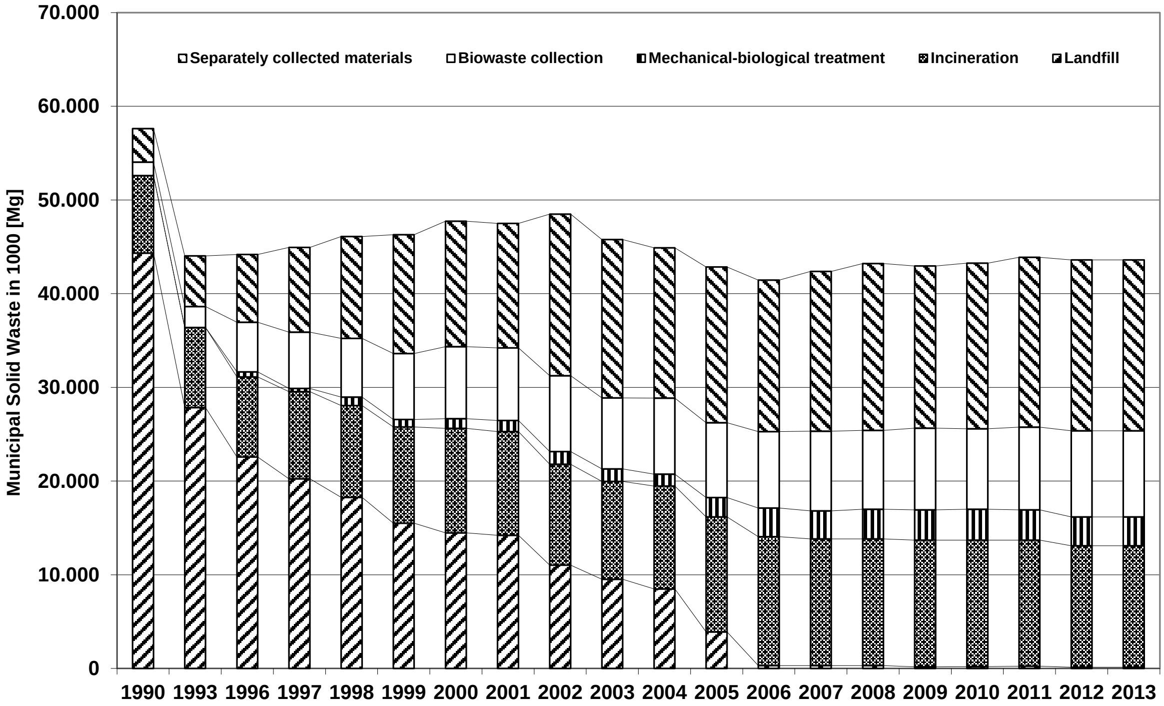

Figure 78: Changes in pathways for management of settlement waste, 1990 to 2013, with intermediate years

By reducing landfill methane emissions from 1.3 million Mg CH_4 in 1990 to 0.4 million Mg in 2013, Germany's waste-management sector has made an important contribution to climate protection. The lower methane emissions from category 5.A.1 amount to a decrease of 24 million tonnes of CO_2 equivalents per year and, thus, to a 2.2 % reduction of Germany's entire greenhouse-gas emissions. Experience gained by Germany's waste-management sector shows that reductions of landfilled quantities of biodegradable waste can provide significantly higher contributions to climate protection than can collection and treatment of landfill gas.

7.2.1.2 Methodological issues (5.A.1)

The method that the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* present for calculation of CH_4 emissions from landfills is based on the "first order decay" method (FOD method). The tier-classification scheme is oriented to use of high-quality national data. The method used in Germany lies between Tier 2 and Tier 3. The Tier 3 method requires national / country-specific key parameters for DOC, DOC_F and half-lives (k values). Germany uses country-specific DOC values, but it uses default values for DOC_F and k values.

The following section describes the FOD method, and the relevant parameters used, for determining methane formation in landfills. The FOD method uses the following equations:[130]

Equation 43: *(2006 IPCC Guidelines for National Greenhouse Gas Inventories, Equation 3.6)*

$$CH_4\ produced\ in\ year\ t\ \left(\frac{Gg}{year}\right) = DDOCm\ decomp_t\ \times F \times 16/12$$

130 A detailed description of the FOD method and its parameters is presented in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, in the Greenhouse Gas Inventory Reference Manual, known as the "IPCC Guidelines" (IPCC 1996b), and in the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, known as the "Good Practice Guidance" (IPCC 2000).

where:

CH_4 produced in year t	*= quantity of CH_4 produced by relevant biologically degradable waste.*
DDOCm decomp$_T$	*= mass of the biodegradable DOC that decomposes in year T*
F	*= percentage share of CH_4 with respect to landfill gas*
16/12	*= factor for conversion of C to CH_4*
t	*= inventory year*

The following also holds:

Equation 44: (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Equation 3.2)

$$DDOC_m = W \times DOC \times DOC_f \times MCF$$

where:

DDOCm	= mass of biodegradable and landfilled DOC, (Gg)
W	= mass of landfilled waste (Gg)
DOC	= share of biodegradable organic carbon in the year in which landfilling takes place (Gg C/Gg waste)
DOCf	= share of DOC that is biodegradable
MCF	= methane-correction factor for year x

Germany uses the IPCC Waste Model, which was developed on the basis of Equations 3.4 and 3.5 of the 2006 IPCC Guidelines. Under this approach, the total quantity of biodegradable DOC in landfills is calculated for each year, in order to calculate the quantity of DOC that is broken down, in each year, into CH_4 and CO_2:

Equation 45: (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Equation 3.4)

$$DDOCma_t = DDOCmd_t + (DDOCma_{t-1} * e^{-k})$$

where:

t	*= inventory year*
DDOCma$_t$	*= DDOCm accumulated in the landfill at the end of year t (Gg)*
DDOCma $_{t-1}$	*= DDOCm accumulated in the landfill at the end of year t-1 (Gg)*
DDOCmd$_t$	*= DDOCm added to the landfill in year t (Gg)*
k	*= constant methane-production rate (1/year)*

Equation 46: (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Equation 3.5)

$$DDOCm\,decomp_t = DDOCma_{t-1} \times (1 - e^{-k})$$

where:

t	= inventory year
DDOCdecomp$_t$	= DDOCm that decomposes in the landfill in year t (Gg)

A multi-phase model was applied. In addition, the calculation was carried out with different half-lives for the different waste fractions involved, and the results so obtained were summed.

To obtain the final CH_4-emissions result, methane that is collected and then flared, or then used for energy recovery, is deducted, and a correction factor is applied that accounts for methane oxidation in landfill covering layers, as shown by Equation :

Equation 47: *(2006 IPCC Guidelines, Equation 3.1)*:

CH_4 emitted in year t (Gg/year) = (CH_4 produced in year t – R(t)) • (1- OX)

Where

R(t) = CH_4 collection in year t
OX = Oxidation factor (fraction)

With the IPCC Waste Model, users may define a time period during which landfilled waste has not yet begun producing gas, i.e. a period of delay until gas formation begins. The 2006 IPCC Guidelines recommend 6 months as a standard value for this delay period. As a result of discussions with national waste experts, and on the basis of measurements of CH_4 formation following landfilling, a delay-period value of 3 months has been chosen. This change has only a slight effect on emission calculations.

For purposes of calculation, the relevant quantities of settlement waste (MSW_T), and the fraction of settlement waste that is landfilled (MSW_F), must be determined. For the FOD method, settlement-waste-production quantities have to be determined throughout the past few decades. Pursuant to the 2006 IPCC Guidelines, estimates should be made of the different waste-type fractions contained in landfilled settlement waste, since the further emissions-calculation procedure is based on the fact that different waste types have different DOC values.

7.2.1.2.1 Quantities of landfilled waste

The FOD model calculates emissions from landfilled settlement waste, landfilled industrial waste and landfilled sewage sludge.

Pertinent quantities of landifilled settlement waste (household and commercial waste) are taken from relevant statistics of the Federal Statistical Office, which are based on annual surveys of waste types, origins and final destinations, as well as on surveys taken of waste-storage facilities, every two years, that focus on specific aspects of the facilities' equipment. The surveys of landfilled quantities of settlement waste in the old German Länder commenced in 1975, on the basis of the Environmental Statistics Act of 1974. Waste quantities for the period from 1950 to 1975 were extrapolated on the basis of population data.

For the new German Länder, data on landfilled quantities of settlement waste, differentiated by Länder, are available for the years 1990 and 1993. For the 1980s in the former GDR, LALE (2000) has presented data that provide information about per-capita landfilled quantities of waste, waste composition, landfill types and types of waste storage involved. The per-capita quantities of landfilled waste in the former GDR, at 190 kg/person, were considerably lower than the corresponding quantities in the old German Länder (330 kg / person and year). The reason for this was that larger percentages of waste were recycled in the former GDR. In 1990, the year of German reunification, landfilled quantities of waste increased sharply in the new German Länder, to the extent that the relevant per-capita quantities even outstripped the corresponding quantities in the old German Länder. The reasons for this were that the former GDR's recycling systems collapsed in that year and that a flood of new products suddenly became available, leading to high levels of replacement purchases and to sharply increasing quantities of packaging waste. Since 1990, per-capita waste quantities in both parts of Germany have slowly been moving into alignment. In the former GDR, all non-recycled waste quantities were landfilled.

Since 1996, the Federal Statistical Office has published differentiated data on waste-landfilling by industry. The relevant inventory takes account of the landfilled waste quantities from industrial sectors as follows:

- Waste from agriculture, horticulture, forestry, fisheries and food processing
- Waste from wood processing

- Waste from production of pulp, paper and carton
- Waste from the textile industry
- Packaging waste, absorbent and filtration materials, wiping cloths and protective clothing
- Wood fractions in construction and demolition waste (data since 1975)

The quantities of industrial waste landfilled between 1975 and 1996 were derived on the basis of total quantities of landfilled waste. While the total quantities include industrial waste, the total-waste figures are not broken down to show industrial waste separately. Extrapolations between waste production and production data of relevant sectors, for the 1996-2002 period, produced no satisfactory statistical relationships. While production figures increased, waste-production figures decreased – considerably, in part – as a result of changes in production processes. Due to the lack of statistical relationships, the figures for landfilled waste quantities were kept constant for the period between 1950 and 1975. Changes in assumptions relative to industrial waste in the 1950-1970 period have only a very marginal effect on emissions in the base year.

7.2.1.2.2 Waste composition

For the inventory calculations, landfilled waste has to be divided into the landfill-waste fractions organic waste, garden and park waste, paper, wood, diapers and textiles, composite materials, sewage sludge and MBT output. To some extent, waste statistics include separate listings for these categories. On the other hand, such statistics also include landfilled quantities of mixed settlement waste that, for calculation purposes, have to be subdivided into the aforementioned fractions. To this end, numerous studies of the components of mixed settlement waste were evaluated, with a view to determining the historical development of waste fractions (organic waste, garden and park waste, paper, wood, diapers and textiles, composite materials). In the years 1980 and 1985, mixed-waste compositions were determined for the entire territory of the former Federal Republic of Germany (Federal Environment Agency (UBA) 1983, 1986). For the subsequent period, a large number of individual studies exists – studies carried out by individual cities, administrative districts and Länder. Some of these had already been evaluated and combined within overarching studies. The pertinent figures were used to obtain time series for waste composition for the period between 1980 and 2013 (cf. Figure 79). Such evaluation of existing studies was carried out for household waste, household-like commercial waste and bulky waste, categories that are listed separately in national statistics. As to waste composition in the new German Länder, the figures provided by LALE (2000) for the 1980s in the former GDR were adopted (composition of household waste: 28 % vegetable waste, 14 % paper/cardboard, 2.3 % wood, rubber, composites, 3 % textiles; household waste accounted for only 16 % of total landfilled waste quantities, however). Quantities of settlement waste landfilled in the former GDR contain smaller fractions of biodegradable materials and large inorganic fractions (primarily ash from household combustion systems). Food waste was collected and used as feed; feeds tended to be scarce during certain periods of time. Paper was collected; it was also a scarce resource. Wood and paper were often burned in ovens for purposes of heating and cooking. The "SERO" recycling system efficiently collected the country's relatively small fractions of plastic packaging. Deposit systems were operated for glass, and glass was also collected. All in all, the former GDR's economy was subject to scarcities of resources, and this led to efficient waste recycling. Ash from household combustion systems accounted for large fractions of landfilled quantities of household waste.

In 2014, existing evaluations of waste-composition studies were reviewed, and more-recent studies of residual-waste composition in the period 2006 through 2013 were identified (6 studies) and evaluated. These more-recent studies confirmed existing assumptions regarding the composition of mixed-waste fractions, and thus the relevant data were carried forward without change. After 2005, landfilling of mixed settlement waste decreased dramatically, as a result of changes in applicable laws (from 5.8 million tonnes in 2004 to 2,000 tonnes in 2013). The need for precise determination of residual-waste fractions for the period as of 2005 has diminished correspondingly, and thus the Federal Government, and the country's Länder, administrative districts and municipalities, have commissioned fewer numbers of studies of waste composition since then.

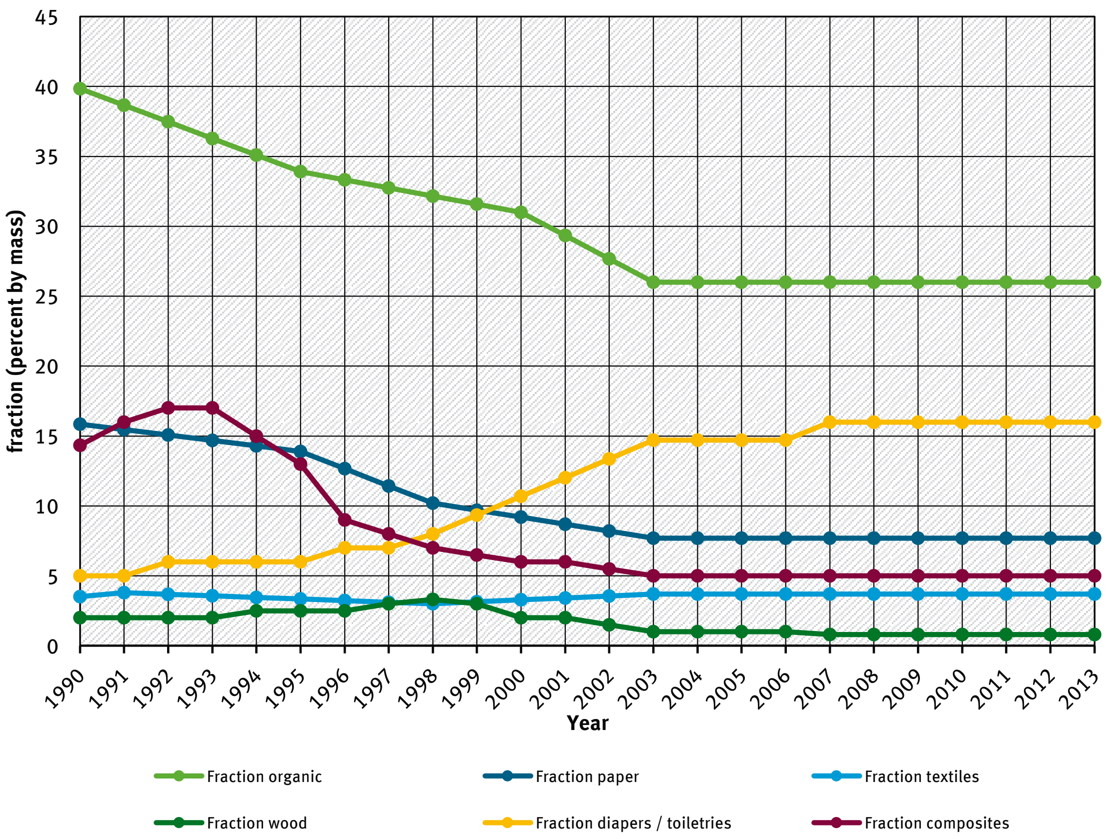

Figure 79: Trends in household-waste composition between 1990 and 2013

Since 1 June 2005 only waste with a total carbon content < 3 %, and mechanically and biologically treated settlement waste, may be landfilled in Germany. Since that time, landfilled waste quantities have decreased very sharply and now make only very small contributions to gas formation. Table 326 outlines the development of quantities of landfilled biodegradable waste. Biodegradable waste fractions have decreased further with respect to 2009. No data are yet available for 2013. Therefore, it has been assumed that waste quantities and waste composition have remained unchanged with respect to 2012.

Table 326: Quantities of biodegradable waste landfilled between 2002 and 2012, broken down by waste fractions

Waste fraction	Units	2002	2003	2004	2005	2006	2007	2008	2009
Organic	1000 t	2.513	2.064	1.831	813	28	13	12	5
Garden and park waste	1000 t	43	43	49	26	19	25	23	1
Paper	1000 t	1.191	1.095	974	426	10	5	6	6
Diapers and textiles	1000 t	1.856	1.720	1.276	519	30	13	13	5
Wood	1000 t	860	709	529	238	10	11	5	1
Composite materials	1000 t	481	398	349	155	5	2	2	1
Sewage sludge	1000 t	369	308	624	634	130	129	133	31
Output from MBT facilities	1000 t	1.226	1.108	990	1.170	1.177	1.266	1.253	1.113
Waste fraction	**Units**	**2010**	**2011**	**2012**	**2013**				
Organic	1000 t	6	5	0	0				
Garden and park waste	1000 t	0	0	0	0				
Paper	1000 t	7	6	2	2				
Diapers and textiles	1000 t	5	5	2	2				
Wood	1000 t	0	0	3	3				
Composite materials	1000 t	1	1	0	0				
Sewage sludge	1000 t TM	27	34	67	67				
Output from MBT facilities	1000 t	991	934	764	764				

During the 2010 inventory review, the review team requested that CH_4 emissions from landfilled MBT residues also be included in calculation of emissions from landfilling. While that fraction has now been included, there is no unambiguous method for that waste category, nor are there suitable national parameters for it. Furthermore, no results have yet been obtained with regard to the behaviour of landfilled waste from MBT facilities (i.e. behaviour in real landfills). Only laboratory data have been obtained to date, and thus the results in this area are subject to very high levels of uncertainty. The mechanical biological (waste) treatment (MBT) process is described in Chapter 7.5.2.

In 2011/12, the residual-gas emissions from landfill storage of mechanically and biologically treated waste were quantified in an expert opinion (IFAS, 2012). The opinion confirms that emissions calculations to data have been correct in applying low emissions contributions from landfilling of MBT waste.

In keeping with the recommendations provided in the inventory review 2010 (paragraph 146, FCCC/ARR/2010/DEU), additional information is provided in this regard as of the 2011 report. Table 327 shows the per-capita waste quantities landfilled, per day, between 1990 and 2013. Those values do not represent the per-capita waste-production rate that is to be reported, as additional information, in the CRF tables. That figure comprises total waste consumption, taking all waste-management pathways into account. It will be calculated for the next report.

In Germany, landfilling of settlement waste has decreased very sharply since 2005, and that trend is also reflected in the per-capita rate of landfilled household waste.

Table 327: Per-capita quantities of landfilled household waste

	Units	1990	1995	2000	2001	2002	2003	2004
Per-capita quantities of landfilled waste	kg/capita/day	1.612	0.851	0.546	0.507	0.440	0.387	0.334
	Units							
Per-capita quantities of landfilled waste	kg/capita/day	0.178	0.050	0.053	0.043	0.040	0.040	0.040
	Units	**2012**	**2013**					
Per-capita quantities of landfilled waste	kg/capita/day	0.031	0.031					

Table 328: Per-capita quantities of settlement waste

	Units	1995	2000	2001	2002	2003	2004	2005
Production of settlement waste per capita	kg/capita/day	1.707	1.802	1.802	1.752	1.647	1.608	1.547
	Units	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Per-capita quantities of landfilled waste	kg/capita/day	1.545	1.596	1.616	1.623	1.650	1.713	1.693
	Units	**2013**						
Per-capita quantities of landfilled waste	kg/capita/day	1.693						

7.2.1.2.3 MCF (methane-correction factor)

Until 1972, when the first Waste Act was introduced, waste was usually stored in uncontrolled landfills; such landfills were closed after 1972. After 1972, waste was stored in managed landfills. In keeping with this history, a default MCF value of 0.6 was used for "unclassified landfills" ("nicht zugeordnete Deponien"), while an MCF of 1 was used after 1972.

Data are available from a 1989 survey of the territory of the former GDR that covered 120 managed landfills, some 1,000 controlled storage sites and some 10,000 uncontrolled dump sites (MNUW, 1990). Of the some 13,000 waste-storage sites, a total of 11,000 were for household waste and 2,000 were for industrial waste; most of the latter were plant-owned facilities (BMU, 1990: p. 28). Consequently, an MCF of 0.6 (default value for unclassified landfills) was assumed for the territory of the former GDR for the period 1970 to 1990. Upon German reunification, the Federal Republic of Germany's waste laws were extended to the territory of the new German Länder, and transitional regulations were introduced to ensure that facilities – including both decommissioned facilities and still-operational facilities in which waste was (or is) produced or disposed of – were accounted for and that suitable clean-up measures were initiated (BMU, 1990: p. 46). Uncontrolled landfills were closed in 1990, facilities permitted to remain open were secured, cleaned up and modernised/expanded in keeping with the standards of Federal German waste law, and sites for new facilities were sought. As of 1990, the Federal Statistical Office has collected statistics on both parts of Germany. For purposes of calculation for the period after 1990, an MCF of 1 is used for all of Germany's territory.

7.2.1.2.4 DOC

Both national data and IPCC default factors are used for DOC, the proportion of degradable organic carbon in waste. Table 329 below provides an overview of the DOC values used.

With regard to dry matter, the 2006 IPCC Guidelines give a default DOC of 50%, which is computationally equivalent to a dry-matter content of about 10%. From the 1980s until 2005, virtually all of the sewage sludge that was landfilled was mechanically dewatered sludge with a dry-matter content of about 30%. A weighted mean DOC of 15% has been derived on the basis of the dry-matter content of the total quantity of municipal and industrial sewage sludge landfilled over time. Since 1 June 2005, only waste with a total carbon content < 3 % may be landfilled in Germany. This also applies to sewage sludge. Computations use a DOC of 3% for the period as of 2006, because sewage sludge may be landfilled only if it has undergone proper pretreatment or if the relevant industrial wastewater has been proven to have suitably low carbon-content levels.

In addition, an error in the calculations for sewage sludge has been corrected. Previously, computations used a DOC of 50% for data with weights expressed as dry matter. The reason for this was that when development of the calculation model began, tonnes of dry matter were the only units used in the data on landfilling of sewage sludge. Several years ago, the activity data in this area were harmonised, with the result that now all data on landfilled quantities of waste, throughout the time series, are obtained from only one data source, Fachserie 19, Reihe 1. That source lists landfilled quantities of sewage sludge in tonnes of wet matter. Previously, data on landfilling of sewage sludge were taken from waste statistics, which listed the data in tonnes of dry matter. The single data source that the harmonisation in the statistical reporting for this area has specified is consistent in its choice of units. This enhances transparency and reduces the potential for error in calculations. Until now, the following implications of this change had been overlooked, however: the DOC value for sewage sludge needed to be adjusted for use of wet-content data; and the DOC of 50% for dry matter needed to be replaced with a figure of 15% for mechanically dewatered sewage sludge. These corrections in the 2015 Inventory have resulted in considerably lower emissions quantities for earlier years in the time series.

Table 329: DOC values used

Fraction	DOC	Source
Organic	18%	Various national studies show DOC levels that are higher than the IPCC default value
Garden and park waste	20%	National value
Paper and cardboard	40%	IPCC default
Wood and straw	43%	The national value is somewhat higher than the IPCC default
Textiles	24%	National value
Diapers	24%	National value
Composite materials	10%	National value
Sewage sludge	15%	Determined computationally from the IPCC default for sewage sludge, oriented to dry matter; after 2006, a DOC of 3% is used
Waste from MBT facilities	0.1%	National value (10 % of the average DOC of landfilled fractions from the current year)

7.2.1.2.5 DOC_F

DOC_F, the DOC fraction that can be converted into landfill gas, is put at 50 % for settlement waste, on the basis of a national study (RETTENBERGER et al, 1997: p. 277). That value is in keeping with the IPCC default of 0.5.

7.2.1.2.6 F = Fraction of CH_4 in landfill gas

A figure of 49% is assumed for F. That value is based on data of the Federal Statistical Office for the years 2004 through 2012. Those data are based on statistical figures, on gas composition, provided by all landfills subject to reporting obligations.

In earlier inventory reports (through the 2014 NIR), the CH_4 fraction in landfill gas was put at 50 %; in the 2015 NIR, that parameter has been reduced to 49 %, in keeping with the most recent statistical data.

Table 330: Fraction of CH_4 in landfill gas

	2004	2006	2008	2010	2012
Fraction of CH_4 in landfill gas	49%	50%	49%	48%	48%

Source: FEDERAL STATISTICAL OFFICE, Fachserie 19, Reihe 1, 2012, Table 1.5

7.2.1.2.7 Half-life

The calculation model is a multi-phase model that takes account of the different half-lives of different waste fractions. Table 331 shows the half-lives and the methane-formation rate used for the pertinent waste fractions. In conformance with the recommendations provided in the 2010 inventory review (paragraph 146, FCCC/ARR/2010/DEU), additional information has been provided for reporting as of 2011. The constant methane-production rate that appears in the FOD method corresponds to the time required for biodegradable organic carbon in waste to decompose to the point at which it has lost half of its original mass. It thus can be derived from the half-lives of the various relevant fractions, in keeping with Equation 48.

Equation 48: (2006 IPCC Guidelines)

$$k = \ln 2 / t_{1/2}$$

Table 331: Half-lives and constant methane-formation rates of waste fractions

Type of waste	Half-life (years)	CH_4-formation rate (k value)
Food waste	4	0.173
Garden/park waste	7	0.099
Paper / cardboard	12	0.058
Wood	23	0.030
Textiles / diapers	12	0.058
Composite materials	12	0.058
Sewage sludge	4	0.173
Waste from MBT facilities	12	0.058

7.2.1.2.8 Landfill-gas use

The "TA Siedlungsabfall" of 1993[131] made gas collection one of the prerequisites for licensing of landfills for settlement waste. The amended version of the Environmental Statistics Act (UStatG) of 2005 mandates that in future the Federal Statistical Office, in its surveys, is to take account of, and publish, levels of landfill-gas collection. For the years 2004, 2006 and 2008, and with regard to landfill-gas collection and use, Fachserie 19 of 12 July 2012 includes only data for landfills in operation and closure phases. Collection of gas-collection data for all landfills, i.e. including landfills in the aftercare phase, began for the first time for the year 2010 and has been reported for the years 2010 and 2012.

As a result of the above-described data gaps, in reporting in recent years (up to and including the 2012 NIR), total quantities of collected landfill gas have been determined by combining data from the energy sector and from Fachserie 19. The data obtained for all landfills as a whole, for the years 2010 and 2012, show that the quantities of gas collected at landfills in the aftercare phase have been considerably overestimated. For this reason, a recalculation had to be carried out to correct the amounts of gas collected at landfills in recent years and, thus, to correct the relevant methane emissions. The quantities of methane listed in Table 17 include both the landfill-gas quantities used for energy generation and those flared off.

[131] Technical instructions on recycling, treatment and other management of settlement waste (Third general administrative provision on the Waste Act (Abfallgesetz)) of 14 May 1993

Table 332: Methane collection in landfills

Year	NIR 2012			NIR 2015				
	Methane formation, in Gg	Collected quantity of methane, in Gg	Collection rate in %	Methane formation, in Gg	Collected quantity of methane, in Gg			Collection rate in %
					Waste-addition and closure phases	Aftercare phase	Total quantity	
1990	2,169	126	5.8	1,581			92	5.8
1991	2,228	136	6.1	1,681			103	6.1
1992	2,246	146	6.5	1,736			113	6.5
1993	2,223	156	7.0	1,751			123	7.0
1994	2,167	166	7.7	1,735			133	7.7
1995	2,095	176	8.4	1,703			143	8.4
1996	2,008	190	9.5	1,657			157	9.5
1997	1,906	260	13.6	1,597			218	13.6
1998	1,801	280	15.5	1,528			238	15.5
1999	1,703	349	20.5	1,461			242	16.6
2000	1,611	352	21.8	1,395			246	17.6
2001	1,520	356	23.4	1,326			247	18.7
2002	1,441	360	25.0	1,262			249	19.7
2003	1,355	363	26.8	1,196			248	20.8
2004	1,280	425	33.2	1,133	*236*	11	247	21.8
2005	1,202	447	37.2	1,070			247	23.0
2006	1,120	460	41.1	996	*231*	11	242	24.3
2007	1,026	445	43.4	916			220	24.1
2008	943	374	39.7	845	*190*	11	201	23.8
2009	874	358	41.0	781			191	24.4
2010	816	347	42.5	723	*171*	*11*	*181*	25.0
2011	752			671			167	24.9
2012	624			624	*140*	*14*	*154*	24.7
2013	624			582			144	24.7

italics: Data of the Federal Statistical Office (Fachserie 19, Reihe1, 2012, of 29 July 2014)

For the recalculation, it was necessary to close data gaps via extrapolation and qualified estimates, since official statistical data are available only for certain single years.

For the years through 1998, proportional gas-collection rates (i.e. expressed as percentages) from earlier estimates continue to be used (cf. the 2012 NIR for the relevant sources and data derivation), and the collected quantities of methane have been calculated from the methane formation and the pertinent collection rate (expressed as a percentage).

For the years 1999 through 2003, the proportional collection rates (expressed as percentages) have been interpolated from the values for 1998 (old method) and 2004. The collected quantities of methane were calculated from the total methane formation and the relevant proportional collection rate (expressed as a percentage).

For the years 2004, 2006 and 2008, Federal Statistical Office (StaBA) data are available only for landfills in waste-addition and closure phases. The total quantities of methane collected at all landfills were determined by adding a) the methane quantities determined for 2010, for landfills in the aftercare phase, and b) the pertinent annual figures for 2004, 2006 and 2008.

For the years 2010 and 2012, the Federal Statistical Office has complete data on landfill-gas collection at all landfills. For the years 2005, 2007, 2009 and 2011, no data on collected quantities of landfill gas are available, since the Federal Statistical Office collects such data only every other year. For those years, the proportional (percentage) rates of landfill-gas collection were thus obtained via interpolation between the relevant previous and subsequent years, and the collected quantities of gas were then calculated from the gas formation and the applicable proportional (percentage) collection rate. For 2013, with this approach, the proportional (percentage) collection rate for 2012 was used.

7.2.1.2.9 Oxidation factor

As to the factor determining the proportion of CH_4 that is oxidised in landfill covering layers, the IPCC default value of 0.1 was adopted for the entire time series. While in the early 1990s the former GDR probably had a higher percentage of uncontrolled landfills than did the old German Länder, a research project has found that the former GDR's landfills have a low CH_4-formation potential, and thus use of the factor 0.1 is also justified for that period (BMBF, 1997).

7.2.1.3 Uncertainties and time-series consistency (5.A.1)

The method's uncertainties were estimated for the first time for the 2006 NIR.

Over the long, 30-year period covered by the activity data, inconsistencies in the time series are unavoidable, since the pertinent waste categories and survey methods changed several times as a result of improvements in legislation and waste statistics. In Germany, special problems arise especially via German reunification and the resulting merging of two different economic and statistical systems. For this reason, considerable effort has to be invested in reviewing data consistency and allocations to the reported categories, in the interest of making time series as consistent as possible.

7.2.1.4 Category-specific quality assurance / control and verification (5.A.1)

General and category-specific quality control and quality assurance, in conformance with the requirements of the QSE manual and its associated applicable documents, have been carried out.

The selected parameters were compared with relevant data for other countries.

In entry of data, the correctness of entries was checked via sum values – various waste categories were recorded solely for the purpose of checking correctness of data entry.

The national calculation model used to date was reviewed via the IPCC's FOD model – i.e. by entering the same pertinent parameters and data into that FOD model. The same result was obtained.

7.2.1.5 Category-specific recalculations (5.A.1)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

7.2.1.6 Planned improvements (category-specific) (5.A.1)

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

7.3 Biowaste treatment (5.B)

In category 5.B, emissions from composting systems (5.B.1) and from fermentation of biowaste in biogas plants (5.B.2) are reported.

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/T	5.B Biological treatment of solid waste		CH4	25,3	(0,00%)	737,6	(0,08%)	2810,8%
-/-	5.B Biological treatment of solid waste		N2O	16,0	(0,00%)	317,6	(0,03%)	1889,4%

The category *Biological treatment of solid waste* is a key category for CH_4, in terms of emissions trend.

7.3.1 Biowaste treatment – composting systems (5.B.1)

7.3.1.1 Category description (5.B.1)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	CS	NS	CS
N_2O	CS	NS	CS

In Germany, annually increasing fractions of biodegradable waste are being separately collected and treated. Composts and digested slurry produced from such separately collected kitchen and garden waste are used for agricultural and horticultural purposes. The 2006 inventory report included a first report on CH_4 and N_2O emissions from treatment of biowaste in composting systems, along with a complete time series for those emissions. In the 2015 NIR, reporting in this area has been brought into line with the 2006 IPCC Guidelines.

7.3.1.2 Methodological issues (5.B.1)

Nitrous oxide emissions from composting of kitchen and garden waste systems are reported in keeping with the 2006 IPCC Guidelines. On the other hand, we use our own national emission factors, obtained via a research project. In the relevant research project, emission factors for methane emissions were also determined. This has eliminated any need to offset methane quantities formed against methane quantities used. The methane and nitrous oxide emissions are calculated in accordance with the following formula:

$$E = M * EF$$

E = emissions in kg
M = mass of biowaste in Gg (1000 t)
EF = g/t (kg/Gg)

Activity data

Since 1980, the Federal Statistical Office has regularly collected and published data on waste quantities managed in composting facilities (Statistisches Bundesamt, Fachserie 19, Reihe 1 of 29 July 2014). To this end, it carries out exhaustive surveys of waste treatment facilities.

The activity data for the current report year have to be estimated, since official waste statistics are published with a one-year time lag. For purposes of estimation, the waste-quantity figure from the previous year is used, unchanged. Recalculations for the year prior to the past year thus have to be carried out on an annual basis. In each case, such estimates are replaced in the following year with the relevant figures from survey statistics.

Table 333: Waste quantities added to biowaste composting facilities

[in 1000 t]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Composting	724	1,515	1,956	2,397	3,783	5,168	6,554	7,214	7,320	7,964
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Composting	9,030	8,562	9,459	9,200	8,981	8,886	8,754	9,115	8,895	8,728
	2010	2011	2012	2013						
Composting	8,609	8,793	8,886	8,886						

Emission factors

Emission factors for composting of biowaste were determined in the framework of a research project (Cuhls et al. 2014). In that project, emissions measurements, covering methane, nitrous oxide and ammonia, were carried out at 19 composting facilities. From the results of those measurements, and from findings obtained via study of the literature, emission factors were extrapolated for the complete group of such facilities in Germany.

The following emission factors were obtained for composting of biowaste:

EF-CH_4 = 1,400 g CH_4/Mg biowaste

EF-N_2O = 74 g N_2O/Mg biowaste

These national emission factors were used for the inventory calculations.

7.3.1.3 Uncertainties and time-series consistency (5.B.1)

Activity data

The uncertainties for the composted waste quantities are considered very small (2 %), since the relevant data were obtained via an exhaustive survey, the reporting quality is good and operators have an interest in high-quality reporting.

Emission factors

The uncertainties for the emission factors are high. They depend on the type of facility/plant in question, on waste composition and on the effectiveness of the biofilters used. The pertinent figures from the literature and from other countries vary so widely that uncertainties of +60 % to -30 % for CH_4, and of at least +100 % to -50 % for N_2O, are assumed.

7.3.1.4 Category-specific quality assurance / control and verification (5.B.1)

General quality control, and quality assurance in conformance with the requirements of the QSE manual and its associated applicable documents, have been carried out.

7.3.1.5 Category-specific recalculations (5.B.1)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

7.3.1.6 Planned improvements (category-specific) (5.B.1)

At present, no further improvements are planned. Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

7.3.2 Biowaste treatment – fermentation plants (5.B.2)

7.3.2.1 Category description (5.B.2)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	CS	NS	CS
N_2O	/CS	NS	CS

In Germany, annually increasing fractions of biodegradable waste are being separately collected and treated. Composts and digested slurry produced from such separately collected kitchen and garden waste are used for agricultural and horticultural purposes. The 2006 inventory report included a first report on CH_4 and N_2O emissions from treatment of biowaste in composting facilities, along with a complete time series for those emissions. Biowaste fermentation in biogas plants has been growing in importance, and statistical surveys of such fermentation have been carried out since 1998. As of the 2015 NIR, therefore, and in keeping with the 2006 IPCC Guidelines, the inventory now also reports on biowaste fermentation in biogas plants.

7.3.2.2 Methodological issues (5.B.2)

Nitrous oxide emissions from fermentation of kitchen and garden waste are reported in keeping with the 2006 IPCC Guidelines. On the other hand, we use our own national emission factors, obtained via a research project. In the relevant research project, emission factors for methane emissions were also determined. This has eliminated any need to offset methane quantities formed against methane quantities used. The methane and nitrous oxide emissions are calculated in accordance with the following formula:

$$E = M * EF$$

E = Emissions in kg
M = Mass of biowaste in Gg (1000 t)
EF = g/t (kg/Gg)

The quantities of gas from biowaste fermentation that are used for energy generation, and the gas quantities that are flared off, are also reported; these data have been included in waste statistics since 2004.

Activity data

Since 1998, the Federal Statistical Office has regularly collected and published data on quantities of waste managed in biowaste fermentation facilities (Statistisches Bundesamt, Fachserie 19, Reihe 1 of 29 July 2014). To this end, it carries out exhaustive surveys of waste treatment facilities. Since 2004, waste statistics have also included data on the quantities of gas from biowaste fermentation that are used, as well as on those quantities that are flared off. For the pre-2004 period back to 1998, such gas quantities had to be obtained via backward extrapolation.

The activity data for the current report year have to be estimated, since official waste statistics are published with a one-year time lag. For purposes of estimation, the waste-quantity figure from the previous year is used, unchanged.

Table 334: Waste quantities added to biowaste fermentation facilities

[in 1000 t]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Fermentation	0	0	0	0	0	0	0	0	411	821
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Fermentation	1,254	1,812	2,783	3,088	3,410	3,526	3,628	4,119	4,149	4,470
	2010	2011	2012	2013						
Fermentation	4,398	5,370	6,094	6,094						

Emission factors

Emission factors for fermentation of biowaste were determined in the framework of a research project (Cuhls et al. 2014). In that project, emissions measurements, covering methane, nitrous oxide and ammonia, were carried out at 16 fermentation plants. From the results of those measurements, and from findings obtained via study of the literature, emission factors were extrapolated for the complete group of such facilities in Germany.

The following emission factors were obtained for fermentation of biowaste:

EF-CH_4 = 2,800 g CH_4/Mg biowaste

EF-N_2O = 67 g N_2O/Mg biowaste

These national emission factors were used for the inventory calculations.

7.3.2.3 Uncertainties and time-series consistency (5.B.2)

Activity data

The uncertainties for the waste quantities treated in fermentation plants are considered very small (2 %), since the relevant data were obtained via an exhaustive survey, the reporting quality is good and operators have an interest in high-quality reporting. This also applies to the statistical data collected on the gas quantities from biowaste fermentation facilities that are used and on those that are flared off.

Emission factors

The uncertainties for the emission factors are high. They depend on the type of facility/plant in question, on waste composition and on the effectiveness of the biofilters used. The pertinent figures from the literature and from other countries vary so widely that uncertainties of +60 % to -30 % for CH_4, and of at least +100 % to -50 % for N_2O, are assumed.

7.3.2.4 Category-specific quality assurance / control and verification (5.B.2)

General quality control, and quality assurance in conformance with the requirements of the QSE manual and its associated applicable documents, have been carried out.

7.3.2.5 Category-specific recalculations (5.B.2)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

The 2015 NIR is now introducing (for NIRs) reporting on greenhouse-gas emissions from biowaste fermentation facilities. In addition, it also reports, for the first time, on the quantities of biogas collected in biowaste fermentation facilities. The majority of such gas is used for energy purposes; a smaller amount is flared off.

Recalculations have to be carried out annually for the year prior to the previous year. For this NIR, recalculations have to be carried out for 2012, since the activity data of the Federal Statistical Office appear with a one-year time lag and thus the current report-year data have to be estimated. In each case, such estimates are replaced in the following year with the relevant figures from survey statistics.

7.3.2.6 Planned improvements (category-specific) (5.B.2)

No further improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

7.4 Waste incineration (5.C)

All waste incineration in Germany is carried out with energy recovery; for this reason, and in order to avoid double counting, the resulting emissions are reported in the energy section (CRF 1.A.1.a, Chapter 3.2.6). Because energy is recovered from waste incineration, no emissions from waste incineration occur under 6.C (NO). Only emissions of NO_X, SO_2 and NMVOC from crematoria are reported here. Those emissions are calculated in keeping with the EF default values in the "EMEP/EEA air pollutant emission inventory guidebook 2013".

7.5 Wastewater treatment (5.D)

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/T	**5.D.1 Wastewater Handling**	**Domestic Wastewater**	**CH4**	**1.765,7**	**(0,14%)**	**23,8**	**(0,00%)**	**-98,7%**
-/-/2	**5.D.1 Wastewater Handling**	**Domestic Wastewater**	**N2O**	**938,2**	**(0,08%)**	**397,3**	**(0,04%)**	**-57,7%**
-/-	5.D.2 Wastewater Handling	Commercial Wastewater	N2O	129,9	(0,01%)	118,9	(0,01%)	-8,5%
-/-	5.D.2 Wastewater Handling	Commercial Wastewater	CH4	9,3	(0,00%)	41,4	(0,00%)	347,8%

The category *Wastewater treatment* is a key category for CH_4 emissions in terms of trend (cf. Table 6); it is a key category for N_2O emissions pursuant to Tier 2 analysis. Because relevant emissions have been falling very sharply since 1990, and thus an extremely low emissions level has been attained, the Single National Entity has decided, as part of its resources prioritisation, not to apply the more stringent methods to this category that are required for key categories.

7.5.1 Municipal wastewater treatment (5.D.1)

7.5.1.1 Methane emissions from municipal wastewater treatment (5.D.1 wastewater treatment)

7.5.1.1.1 Category description (5.D.1 Wastewater treatment)

Gas	Method used	Source for the activity data	Emission factors used
CO_2	NA	NA	NA
CH_4	CS	NS	D/CS
N_2O	D/CS	NS	D

CH_4 emissions from municipal wastewater treatment are a key category in terms of trend.

In Germany, municipal wastewater treatment takes place under aerobic conditions (municipal wastewater-treatment plants, small wastewater-treatment plants), i.e. no methane emissions occur (default value for MCF = 0). Methane emissions can occur only under anaerobic conditions.

Treatment of human sewage from inhabitants not connected to sewage networks or small wastewater-treatment facilities represents an exception (0.7 %) (Statistisches Bundesamt, 2013a): wastewater from such inhabitants is collected, for later transport to wastewater treatment plants, in cesspools or septic tanks with no drainage. In cesspools and septic tanks, uncontrolled processes (partly aerobic, partly anaerobic) can occur that lead to methane formation. Since 1990, the organic loads discharged into cesspools and septic tanks have been drastically reduced, however, because the percentages of inhabitants connected to wastewater treatment facilities have continually increased. As a result, this sector's CH_4 emissions show a sharply decreasing trend.

In addition, the open sludge digestion that was carried out, for purposes of sludge stabilisation, in the new German Länder until the early 1990s was gradually reduced and then completely discontinued as of 1994 (cf. Chapter 7.5.1.2.1).

7.5.1.1.2 Methodological issues (5.D.1 wastewater treatment)

The equation presented by the IPCC (Equation 6.1; 2006 IPCC Guidelines) for calculation of CH_4 emissions from municipal wastewater cannot be applied to the situation in Germany. Of the population fractions (U_i) referred to in Table 6.5 of the IPCC Guidelines (ibid.), only one, extremely small source group (mentioned above) – a group that, in terms of CH_4, is not related to wastewater treatment plants and their CH_4 recovery systems – contributes to the reported CH_4 emissions. The wastewater produced by other fractions of the population is treated in wastewater treatment plants that, as noted above, all operate aerobically – and thus produce no CH_4. In addition, primary and secondary sludges are used to generate CH_4 in digestion towers. The resulting methane is collected, and the total quantity of CH_4 produced in the process far exceeds to the CH_4 emissions calculated in the present context. As a consequence, the pertinent value resulting from the IPCC equation would be negative. What is more, the relevant sewage sludge is used only after such treatment, i.e. after it has been fully digested (it is used in for agricultural or landscaping purposes). For this reason, the term "sludge removed" as used within the meaning of the Guidelines is not appropriate, since the sewage sludge no longer has any BOD_5 (cf. also Chapter 7.5.1.2.1). Furthermore, the statistics available in Germany on numbers of persons connected to cesspools and septic tanks are much more precise than the values for U_i and $T_{i,j}$ (degree of utilisation of treatment system) that can be derived with Table 6.5 of the Guidelines. All in all, the 2006 Guidelines method has too much "default" in it to be suitable for the situation actually prevailing in Germany.

For the above-described reasons, instead of with the 2006 IPCC equation, calculation is carried out in accordance with the 1996 IPCC method – with that method supplemented in accordance with the requirements set forth in the 2006 IPCC Guidelines.

Organic loads from cesspools and septic tanks are calculated pursuant to the IPCC method, in which the number of persons connected to cesspools or septic tanks (P) is multiplied by the average organic load per person. The average organic load is assumed to be 60 g BOD_5 per inhabitant (Gujer, 2007). That value is a specific value for Germany. In addition, it is used

Europe-wide as a statistical average value (Official Journal of the European Communities, No L 135/40, 30.5.91, Article 2 No 6) (91/271/EEC 1991). The IPCC default value for Germany (IPCC Guidelines for National Greenhouse Gas Inventories 2006, Chapter 6, Table 6.4, page 6.14), at 62 g, is of a similar order of magnitude.

Methane emissions from cesspools and septic tanks are determined in keeping with the IPCC method. The IPCC default value for methane formation potential (0.6 kg CH_4 / kg BOD_5) has been used.

Pursuant to IPCC 2006 (Chapter 6.1, page 6.7), the methane correction factor (MCF) depends on temperature. No significant methane production occurs at temperatures below 15°C.

In light of the long-term mean soil temperature in Germany (DWD 2013) at a depth of 1 m, the average soil temperature in summer months ranges between 15 and 18°C. Methane thus can form during summer months, since the relevant cesspools and septic tanks are situated at depths averaging between about 0.5 m and 2.5m. In keeping with (GIBBS & WOODBURY, 1993), the MCF for this period (about 3.5 months) is conservatively estimated to be 0.35. Throughout the rest of the year, the temperatures are below – significantly, in part – the IPCC's 15°C boundary. They drop to about 3.8 °C. In keeping with (GIBBS & WOODBURY, 1993), the MCF for this period (about 8.5 months) is estimated to be 0.1. Furthermore, since the cesspools and septic tanks are regularly emptied, for transport of their wastewater to treatment plants, and thus no sedimentation or sludge concentration occurs, the values used are assumed to be realistic or even conservative. The described conditions and temperature distribution in the soil yield a mathematically averaged MCF for Germany of 0.173.

The MCF is determined as follows:

$$MCF = (0.35 * 3.5 \text{ months} + 0.1 * 8.5 \text{ months}) / 12 \text{ months}$$

The emissions are calculated as follows:

$$CH_4 = BOD_{5Y} \times B_o \times MCF$$

$$BOD_{5Y} = P_{\text{cesspool, septic tank}} \times BOD_5 \times 365 \times 0.001$$

Where

MCF	= Methane correction factor, 0.173
B_o	= *Default – max. CH_4 formation capacity, 0.6 kg CH_4 / kg BOD_5*
$P_{\text{cesspool, septic tank}}$	= *Number of persons connected to cesspools or septic tanks*
BOD_{5Y}	= *BOD_5 in g / year*
BOD_5	= *BSB_5, 60 g / day x persons*

Calculation pursuant to Tier 3, as required for key categories, is not feasible, since the substance flows for cesspools and septic tanks are not separately recorded.

7.5.1.1.3 Uncertainties and time-series consistency (5.D.1 wastewater treatment)

The MCF value has been adjusted in keeping with the climatic conditions prevailing in Germany (long-term average soil temperature in Germany). The uncertainty for the value is ± 20 % (expert estimate).

The following uncertainties are also used (all are expert estimates):

Inhabitants with cesspools or septic tanks	= ± 3 %
BOD_5	= ± 30 %
Bo	= ± 30 %

The activity data for the organic loads in cesspools and septic tanks are based on figures of the Federal Statistical Office (Fachserie 19 Reihe 2.1 and Fachserie 19 Reihe 2.1.3). Every three years, the Federal Statistical Office conducts a survey – without determining the relevant uncertainties – of the numbers of inhabitants who are not connected to the public sewer system and whose wastewater is disposed of via cesspools and septic tanks. Data for interim years are linearly interpolated or extrapolated. No other pertinent data sources are available. The results of such surveys may be considered very precise, since the surveys are exhaustive.

Until 1995, data for the old and new Federal Länder were determined separately; since then, a single value for all of Germany has been determined in each case. This does not affect time-series consistency, however.

7.5.1.1.4 Category-specific quality assurance/ control and verification (5.D.1 Wastewater treatment)

Quality control (pursuant to Tiers 1 + 2) and quality assurance, in conformance with the requirements of the QSE manual and its associated applicable documents, have been carried out.

The fact that aerobic wastewater treatment in relevant facilities produces no significant methane emissions can be confirmed in other countries.

As noted above (Chapter 7.5.1.1.1), 0.7% of the population in Germany are not connected to the sewage network and thus collect their wastewater in cesspools or septic tanks. That value accords quite well with the values proposed by IPCC (2006; Table 6.5), for Germany, for the relevant fraction of the rural population and the associated degree of utilisation of septic systems. With the IPCC values, one obtains the result that about 1.2% of the population collects wastewater via septic systems. The two values are of the same order of magnitude and, additionally, lie quite close together.

7.5.1.1.5 Category-specific recalculations (5.D.1 Wastewater treatment)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

7.5.1.1.6 Planned improvements (category-specific) (5.D.1 Wastewater treatment)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

7.5.1.2 Methane emissions from municipal sludge treatment (5.D.1 Sludge treatment)

7.5.1.2.1 Category description (5.D.1 Sludge treatment)

As a general rule, the treatment of municipal sewage sludge comprises two treatment stages:

- Water removal via mechanical processes (chamber-filter press, cyclone); evaporation in sludge-drying lagoons or sludge-drying beds
- Stabilisation: Aerobic stabilisation (open pool with oxygen input); or anaerobic stabilisation in digestion tower;
- (formerly: open sludge digestion)

With reference to population figures, mechanical *dehydration* + treatment in a digestion tower (with dehydration before or after the digestion-tower treatment) currently represents the main treatment method (some treatment is also carried out in small, rural sewage treatment plants). Moreover, sewage sludge is generally stabilised prior to subsequent use.

The purpose of sludge stabilisation is to prevent uncontrolled sludge digestion. In facilities for fewer than 10,000 inhabitants, such stabilisation is usually carried out aerobically, with energy consumption, while in facilities for more than 30,000 inhabitants it normally is carried out anaerobically, with production of methane gas. The amount of digester gas produced depends especially on the composition of the sewage sludge, the temperature and the reaction conditions. Gas so produced is usually recovered for energy generation in combined heat/power generating systems (CHP). It is reported under 1.A.1. Where facilities are unable to use the methane gas cost-effectively in this manner, or when technical disruptions or overloads of attached CHPs occur, the methane gas may be flared off. This releases insignificant amounts of methane emissions into the environment (≤ 5%).

Until the early 1990s, in eastern Germany sludge was stabilised via open digestion, a process that produced methane emissions. Open sludge digestion is no longer practiced, however. It was phased out gradually, and was then completely discontinued in 1994.

Emissions from open sludge digestion continue to be the reason, however, why NO is reported for this point in the CRF, instead of IE (for the energy-related use under 1.A.1 – see above), since this technique, with its related emissions, was used through 1993. Today, it is no longer used – this is the reason for the "NO".

The secondary sludge (excess sludge) occurring in wastewater treatment, and the pertinent primary sludge, are anaerobically treated, together, in digestion towers (completely digested; see above) and thus anaerobically stablised. That process produces digested sludge. That sludge, in turn, undergoes further treatment in wastewater treatment facilities and leaves such facilities as sewage sludge. Use of this process ensures that the sewage sludge is completely free of readily biodegradable substances.

The sewage sludge and the treated wastewater are the final products of wastewater treatment.

In Germany, sewage sludge remaining after biological wastewater treatment is managed in the following ways (where applicable, after dehydration and stabilisation):

- Thermal disposal: no methane emissions occur. Thermal disposal requires energy inputs and thus is allocated to CRF 1.

- Recycling for substance recovery: the most important procedures for recycling sewage sludge for substance recovery include recycling in agriculture, pursuant to the Ordinance on Sewage Sludge (Klärschlammverordnung), and use in landscaping and other measures. Emissions from recycling for substance recovery are not reported under wastewater and sludge treatment.

Table 335: Use of sewage sludge

Sewage sludge	t dry matter									
	1998	2001	2004	2006	2007	2008	2009	2010	2011	2012
Total quantity	2459177	2429403	2260846	2048507	2055906	2054102	1956447	1887408	1950126	1846441
Thermal disposal	395859	554924	711170	*965115*	*1015014*	*1077624*	*1028034*	*1003749*	*1067431*	*1008830*
Recycling for substance recovery	1490074	1399456	1175694	*1078264*	*1036844*	*973997*	*927516*	*883659*	*882695*	*837611*
- Agriculture	783662	754837	627989	*611598*	592561	*587832*	*589149*	*566295*	*567187*	*544065*
- Landscaping-related measures	175659	190025	170643	399712	368912	331556	282455	259312	254402	235439
- Composting	452891	393244	322125							0
- Other	77862	61350	54937	66954	75371	54609	55912	58052	61106	58107
- Landfills	205140	159673	79052	5128	4048	2481	897			

Source: ((Statistisches Bundesamt, 2013b) (Statistisches Bundesamt, 22 May 2014)

The activity data for sewage-sludge utilisation are based on data of the Federal Statistical Office (Statistisches Bundesamt, 2013b). The relevant report appears every 3 years. The figures for interim years are taken from the publication "Wasserwirtschaft Öffentliche Abwasserentsorgung Klärschlammverwertung aus der biologischen Abwasserbehandlung“ ("Water resources sector, public wastewater management, use of sewage sludge from biological wastewater treatment"; Federal Statistical Office, appears annually)(Statistisches Bundesamt, 22 May 2014). No data are available for the period prior to 1998 and for the years 1999-2000, 2002-2003 and 2005. No interpolation is possible, because a statistical conversion for the period as of 2007 makes it impossible to form a 100% sum (Wiechmann et al. 2013). No figures for the current inventory year are available at present.

7.5.1.2.2 Methodological issues (5.D.1 Sludge treatment)

7.5.1.2.2.1 Digester gas

As described above, the digester gas that is produced by the digestion process is collected and used for energy generation. The methane content in digester gas is nearly 65 % (Schön et al. 1993). The relevant quantity of methane per raw-gas volume (persönliche Mitteilung Statistisches Bundesamt, 2014) is determined as follows:

$$M_{methane} = V_{raw\ gas} \times 0.65 \times \sigma \times 0.000001$$

Where

$M_{methane}$ = mass of methane produced via digestion (kt)

$V_{raw\ gas}$ = volume of digester gas produced (m^3)

0.65 = factor for conversion of digester gas to contained methane

σ = density of methane (0.717 kg/m^3) (v.Vogel 1974)

7.5.1.2.2.2 Flaring (losses)

As described above, the digester gas that is produced by the digestion process is collected and used for energy generation. In gas collection, flaring is used as a safety response in cases of technical difficulties, accidents and other incidents, etc.. Consequently, gas collection can entail flaring losses. All of the gas flares used with relevant gas-collection systems are emergency/shutdown flares; i.e. they also come into play when systems (such as combined heat-and-power (CHP) generating systems) have to be shut down for maintenance purposes. Such gas flares are designed to be able, in emergencies, to burn all of the gas being collected. The gas quantities routed through gas flares are not recorded. However, since the flares are used only as emergency flares, the gas quantities burned during normal system operation are nearly zero. Gas flares are equipped with automatic ignition systems that assure reliable burning of collected gas during disruptions of normal system operation. For this reason, the methane emissions from gas flares are assessed by experts as "zero".

7.5.1.2.2.3 Open sludge digestion

Table 336 lists the emission factors for open sludge digestion and the methane emissions determined for that process.

Table 336: Methane emissions from open sludge digestion, in the new German Länder

	Units	1990	1991	1992	1993	1994
Emission factor	[kg CH_4/t TS]	210	210	210	210	210
Sewage-sludge production	[t TS]	247,190	140,952	72,762	37,524	0
Methane emissions	[t]	51,910	29,600	15,280	7,880	0

Emission factors derived from (UBA 1993)

An emission factor of 210 kg CH_4/t TS is used for open sludge digestion in the new German Länder, in keeping with the results of the study (Schön et al. 1993)[132]. The activity rates for the years 1990 to 1992 were communicated personally to the Federal Environment Agency by the then Chief Inspector of the former GDR's water-processing plants.

In keeping with the fact that open sludge digestion is prohibited in the Federal Republic of Germany, use of that treatment method was gradually reduced in the new German Länder until 1994 and then was completely discontinued as of 1994.

7.5.1.2.3 Uncertainties and time-series consistency (5.D.1 Sludge treatment)

7.5.1.2.3.1 Digester gas

The uncertainties in determination and calculation of the applicable quantities of methane are assessed as follows (expert assessment):

Volume of digester gas produced = ± 5 %

The uncertainties originate in the measurement inaccuracies of the measuring devices used

Methane content in digester gas = ± 15 %

Varies in keeping with the composition of the wastewater – and, thus, of the composition of the sludge

Density = ± 30 %

The literature gives a range of different densities for methane (depending on temperature, etc.)

132 The emission factor was determined via the difference between methane emissions from psychrophilic sludge stabilisation in the new German Länder and the total amount of sewage sludge produced.

7.5.1.2.3.2 Open sludge digestion

Since the uncertainties connected with open sludge digestion have not yet been estimated, the default values (conservative factors) given in UNFCCC Decision 20/CMP.1 (p. 39ff) are used. The activity rates between 1990 and 1992 are based on a personal communication; those for 1993 are based on estimates of the Federal Environment Agency. As a result, a high degree of time-series consistency is not assured.

7.5.1.2.4 Category-specific quality assurance / control and verification (5.D.1 Sludge treatment)

Quality control (pursuant to Tiers 1 + 2) and quality assurance, in conformance with the requirements of the QSE manual and its associated applicable documents, have been carried out.

7.5.1.2.5 Category-specific recalculations (5.D.1 Sludge treatment)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

7.5.1.2.6 Planned improvements (category-specific) (5.D.1 Sludge treatment)

At present, improvements seem neither necessary nor possible, since no further activity data can be obtained.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

7.5.1.3 Nitrous oxide emissions from municipal wastewater (5.D.1 Nitrous oxide emissions from municipal wastewater)

7.5.1.3.1 Category description (5.D.1 Nitrous oxide emissions from municipal wastewater)

Municipal wastewater contains numerous nitrogen compounds. In bacterial decomposition processes, part of the available organic nitrogen is converted back into biomass. So that they can eliminate virtually all of the nitrogen remaining in wastewater, nearly all of the municipal wastewater-treatment plants in Germany are operated with an additional nitrification and denitrification stage that complements the plants' biological wastewater treatment. In nitrification, the nitrogen compounds in the wastewater are converted into nitrate, under aerobic conditions. In denitrification, the nitrogen bound in the nitrate is converted into molecular nitrogen and nitrogen oxides. Under unfavourable conditions (cf. also Chapter 7.5.2.2.1), nitrous oxide (N_2O) can occur as a by-product / intermediate product in both processes, although denitrification is the predominate source in this regard ((IPCC 2006) Chapter 6.1 page 6.8) (direct emissions). The N-elimination efficiency of biological wastewater treatment plants in Germany, for the years 2006-2013, is about 81.2%, (18th - 26th comparison of the performance of municipal wastewater treatment plants (18.-26. Leistungsvergleich Kommunaler Kläranlagen) (DWA 2007-2014), meaning that wastewater continues to contain nitrogen after having undergone the full wastewater treatment process, and that such nitrogen enters water bodies. In water bodies, microbial decomposition processes also take place in which nitrous oxide emissions can occur (indirect emissions).

The total emissions of nitrous oxide that are produced via municipal wastewater are determined as a combination of direct nitrous oxide emissions (N_2O_{Plants}) and indirect nitrous oxide emissions ($N_2O_{Emissions}$). This is expressed as follows:

$$N_2O_{Total} = N_2O_{Plants} + N_2O_{Emissions}$$

The following chapters consider the direct and indirect sources of nitrous oxide emissions.

The emissions show a strongly decreasing trend, as a result of extensive additions of denitrification systems to wastewater treatment facilities in the period 1990 through about 2001. Those additions were triggered by an amendment of the Waste Water Ordinance (Abwasserverordnung)(91/271/EWG 1991), in the early 1990s, that declared that the best available technology for wastewater treatment plants included nutrient removal technology. Nutrient removal technology has since reached high technological standards, and a slightly decreasing trend became established in about 2005.

7.5.1.3.2 Methodological issues (5.D.1 nitrous oxide emissions from municipal wastewater)

Direct emissions

Nitrous oxide emissions can occur as a by-product / intermediate product of biological wastewater treatment with nitrification and denitrification – especially in connection with denitrification (cf. also Chapter 7.5.2.2.1). Pursuant to the 2006 IPCC Guidelines, only countries with modern, centralised wastewater treatment facilities are required to report direct emissions. According to the IPCC, "modern" facilities in this context are facilities with nitrification and denitrification phases. As noted above, nitrous oxide emissions occur primarily in connection with denitrification ((IPCC 2006) Chapter 6.1). For this reason, in the following the fraction of German wastewater treatment plants with denitrification equipment (T_{Plant}) – and not the fraction of plants with nitrification equipment – is used for the calculations. The two fractions are about the same, however. Currently, they are 98 % (nitrification) and 95 % (denitrification).

Pursuant to the 2006 IPCC Guidelines, the nitrous oxide emissions of centralized wastewater treatment plants with denitrification are calculated as follows:

$$N_2O_{Plants} = P \bullet T_{Plant\ deni} \bullet F_{Ind\text{-}comm} \bullet EF_{Plant}$$

Where

N_2O_{Plants} = total annual N_2O emission of plants J, in kg N_2O/year)

P = population

$T_{Plant\ deni}$ = fraction of modern, centralized wastewater treatment plants with denitrification, in %/100

$F_{Ind\text{-}comm}$ = fraction of protein of industrial / commercial origin that is managed via wastewater; default = 1.25

EF_{Plant} = emission factor; 3.2 g N_2O/person x year

While the emission factor for nitrous oxide and the fraction of industrially and commercially discharged protein ($F_{Ind\text{-}comm}$) are IPCC default values, the population figure (P) and the fraction of modern, centralised wastewater treatment plants with denitrification ($T_{Plant\ deni}$) are country-specific values.

Indirect emissions

In keeping with the method proposed by the 2006 IPCC Guidelines, first the total annual quantity of nitrogen in wastewater effluent is determined. For countries with modern, centralised wastewater treatment plants, and taking N_{WWT} into account, this is to be determined as follows:

$$N_{Effluent} = (P \times Protein \times F_{NPR} \times F_{Non\text{-}con} \times F_{Ind\text{-}comm}) - N_{Sludge} - N_{WWT}$$

(Equation: 6.8 IPCC 2006)

Where

$N_{Effluent}$	= total annual quantity of nitrogen in wastewater effluent, in kg N/year
P	= population
Protein	= per-capita protein consumption, in kg/person/year
F_{NPR}	= nitrogen fraction in protein; default = 0.16 kg N / kg protein
$F_{Non\text{-}con}$	= fraction of non-consumed protein in wastewater; default = 1.1
$F_{Ind\text{-}comm}$	= fraction of protein of industrial / commercial origin that is managed via wastewater; default = 1.25
N_{Sludge}	= nitrogen removed with sludge; default = 0 in kg N / year
N_{WWT}	= nitrogen in nitrous oxide occurring during wastewater treatment = N_2O_{Plants} x 28/44 in kg N / year
28/44	= factor for conversion of N_2O to N_2

According to experts, this formula is erroneous, however, and ineffective by itself, since it does not take account of the N-removal performance of wastewater treatment plants' denitrification phases. As noted above in Chapter 7.5.1.3.3, data on the average N content of the wastewater flowing into and out of German wastewater treatment plants are available for the years 2005-2013 (DWA 2007-2014). From those data, biological wastewater-treatment plants in Germany were determined to have an average N-removal efficiency of 81.2 % in the years mentioned. To obtain realistic results, one must adapt the above equation. In the interest of data comparability, $T_{Plant\ biol}$ was determined, via selection of wastewater treatment plants with biological treatment. The factors to be taken into account include a) the removal efficiency of wastewater treatment plants with biological wastewater treatment and b) the N load of all plants without biological wastewater treatment. The factor N_{WWT} does not suffice for this purpose, since it includes only the nitrogen fraction in the nitrous oxide that is produced (direct emissions); it does not include the N fraction in the molecular nitrogen produced via denitrification. The factor N_{WWT} is thus taken out of the equation:

$$N_{Effluent} = (P \times Protein \times F_{NPR} \times F_{Non\text{-}con} \times F_{Ind\text{-}comm}) - N_{Sludge}$$

That formula applies for plants without nitrogen removal.

For calculation of the N load ($N_{Effluent\ with}$) in the effluent of plants with nitrogen removal, a removal factor $F_{Removal}$ is introduced. The formula is thus as follows:

$$N_{Effluent\ with} = ((P \times Protein \times F_{NPR} \times F_{Non\text{-}con} \times F_{Ind\text{-}comm}) - N_{Sludge}) \times (1 - F_{Removal}) \times T_{Plant\ biol.}$$

Where

$F_{Removal}$	= factor for removal of nitrogen in biological wastewater treatment plants (DWA 2007-2014) = 81.2 / 100
$T_{Plant\ biol.}$	= fraction of modern, centralised wastewater treatment plants with biological wastewater treatment, in %/100

$N_{Effluent\ with}$ = N load in the effluent of wastewater treatment plants with biological wastewater treatment
$N_{Effluent\ without}$ = N load in the effluent of wastewater treatment plants without biological wastewater treatment

The N load ($N_{Effluent\ without}$) in the effluent of wastewater treatment plants without biological wastewater treatment is calculated as follows:

$$N_{Effluent\ without} = ((P \times Protein \times F_{NPR} \times F_{Non\text{-}con} \times F_{Ind\text{-}comm}) - N_{Sludge}) \times (1 - T_{Plant\ biol.})$$

Then, the nitrogen loads in the effluent of wastewater treatment plants with biological wastewater treatment and in the effluent of wastewater treatment plants without biological wastewater treatment are added, to yield the total N load in the effluent of all wastewater treatment plants:

$$N_{Effluent} = N_{Effluent\ with} + N_{Effluent\ without}$$

$$= ((P \times Protein \times F_{NPR} \times F_{Non\text{-}con} \times F_{Ind\text{-}comm}) - N_{Sludge}) \times (1 - F_{Removal}) \times T_{Plant\ biol.} + ((P \times Protein \times F_{NPR} \times F_{Non\text{-}con} \times F_{Ind\text{-}comm}) - N_{Sludge}) \times (1 - T_{Plant\ biol.})$$

The result obtained with the above-described procedure has been verified via comparison with alternative data (DWA 2007-2014), and it thus seems to be correct (cf. Chapter 7.5.1.3.6).

The IPCC default values are used for the emission factor for nitrous oxide, the nitrogen fraction in protein, the fraction for non-consumed protein ($F_{Non\text{-}con}$) and for industrially and commercially discharged protein ($F_{Ind\text{-}comm}$). Country-specific values are used for the average per-capita protein intake and the population size (number of persons).

The FAO's figures are used for determination of the average protein intake per person and day:

- For Germany (FAO 2004) and for the years 1989-91, the FAO gives an average protein intake per person and day of 99 g.
- In keeping with the FAO Statistical Yearbook 2007-2008(FAO 2007-2008), the 2010 FAO Statistical Yearbook gives average protein intakes, per person and day, of 95 g (1994-1996), 97 g (1999-2001), 99 g (2003-2005) and 99 g (2005-2007) for Germany(FAO 2010).
- The values for the years 1992-1993 and 2002 are interpolated.
- The values for 1997-1998 represent the arithmetic mean from 1996-1999.
- The values for the years as of 2008 are extrapolated (on the basis of 2003-2007).

The nitrous oxide emissions are determined as follows, in keeping with the IPCC method:

$$N_2O_{Emissions} = N_{Effluent} \times EF_{Effluent} \times 44/28$$

Where
$N_2O_{Emissions}$ = N_2O emissions, in kg N_2O/year
$N_{Effluent}$ = nitrogen discharged into the aquatic environment, in kg N/year
$EF_{Effluent}$ = emission factor for N_2O emissions released into wastewater, in kg N_2O-N / kg N (default = 0.005)
44/28 factor for conversion of N_2O-N to N_2O

7.5.1.3.3 *Uncertainties and time-series consistency (5.D.1 Nitrous oxide emissions from municipal wastewater)*

The following uncertainties are used (all are expert estimates):

P (population)	= ± 5 %
$T_{Plant\ deni}$ (wastewater treatment plants with denitrification)	= ± 5 %
$T_{Plant\ biol.}$ (wastewater treatment plants with biological wastewater treatment)	= ± 5 %
$F_{Ind\text{-}comm}$	= ± 25 %

The activity data are based on data of the Federal Statistical Office. The population of Germany is determined on an annual basis, while the quantity of wastewater treated in wastewater treatment facilities with denitrification is determined every three years (without determination of pertinent uncertainties). The results of the latter surveys may be considered very precise, since the surveys are exhaustive. The figures for the years prior to 1998 have been extrapolated. They are plausible, since inclusion of nitrogen removal processes in wastewater treatment began to be expanded in Germany as of the beginning of the 1990s. The figures for the years after 2010 have been carried forward from earlier years. All other lacking data have been linearly interpolated.

The uncertainties for the EF_{Plant} have been taken from Table 6.11 (2006 IPCC Guidelines); they are - 37.5 % and + 150 %. Experts consider those values plausible.

As noted above, German wastewater treatment plants were determined, via publications, to have an average N-removal efficiency of 81.2 % in the years 2006-2013. No measurement data are available for the years prior to and after that period. The same technological standards have been assumed to apply for the years for which no data are available, and thus the removal efficiency has been considered to be 81.2 % for the entire time series. The uncertainty is estimated as 5 %.

The activity rates for 1989-1991 were taken from the FAO Statistical Yearbook 2004. The data for 1994-1996 and 1999-2001, and for 2003-2007, were taken from the FAO Statistical Yearbook 2007-2008 and 2010 Table D.1. As described in Chapter 7.5.1.3.2, lacking values were obtained via interpolation, extrapolation or calculation of the pertinent arithmetic mean.

Calculations were based on the average daily protein requirements listed by the FAO database, to ensure that the time series is consistent and to prevent any need for extrapolation of individual values. An uncertainty of ± 15 % (expert estimate) is assumed.

The average nitrogen fraction in protein ($Frac_{NPR}$) is 16 % ± 1%. In obtaining this value, it was assumed that Bovine serum albumin is the standard protein. In light solely of the aforementioned standard deviation (± 1%), the uncertainty would be about ± 6 % (with respect to the 16% fraction). It is estimated to total ± 7 %, however, since the relevant wastewater contains a broader spectrum of protein (expert estimate).

In addition, the following uncertainties have also been used (all are expert estimates):

$F_{NON-CON}$, = ± 15 % (expert estimate)

$F_{IND-COM}$ = ± 25 %

The uncertainties for $EF_{Effluent}$ have been taken from Table 6.11 (2006 IPCC Guidelines).

7.5.1.3.4 Source-category-specific quality assurance / control and verification (5.D.1 Nitrous oxide from municipal wastewater)

Quality control (pursuant to Tiers 1 + 2) and quality assurance, in conformance with the requirements of the QSE manual and its associated applicable documents, have been carried out.

The formula, adapted with $F_{Removal}$, for determination of N effluent into waters, was verified via the average values published in the 18th- - 26th comparison of the performance of municipal wastewater treatment facilities (Leistungsvergleich kommunaler Abwasserbehandlungsanlagen) for N discharges into water bodies (DWA 2007-2014). At present, relevant results are available only for the years 2006-2013. The calculation and the survey were carried out independently of each other. Table 8 presents the results of calculations of $N_{Effluent}$ (indirect emissions) using the IPCC 2006 method, the results of calculations using the modified IPCC method (with the nitrogen-removal factor $F_{Removal}$) and the pertinent measurements obtained by the German Association for Water, Wastewater and Waste (DWA).

Table 337: Comparison of results for $N_{Effluent}$ (indirect emissions) obtained with the IPCC 2006 method, with the modified IPCC 2006 method and via the measurements of the DWA; (kt N / year)

	2006	2007	2008	2009	2010	2011	2012	2013
			With the IPCC 2006 method					
$N_{Effluent}$	654.2	653.4	651.7	650.1	649.7	638.4	639.9	639.9
			With the modified PCC 2006 method					
$N_{Effluent}$	137.6	135.5	134.5	133.5	132.7	130.4	130.7	130.7
			Effluent measurements of the DWA					
$N_{Effluent}$[133]	71.5	86.1	86.5	82.7	87.0	77.9	79.1	81.7
$N_{Effluent}$[134]	80.8	90.6	95.4	95.1	92.9	90.9	89.9	88.9

Clearly, the modified method yields significantly lower values for the N load in the effluent ($N_{Effluent}$) than does the IPCC method. What is more, the results calculated for $N_{Effluent}$ are confirmed in that they are of the same order of magnitude as the values measured by the DWA. The discrepancy seen can be ascribed to the default emission factor used. In light of this verification, it must be considered too high. Nonetheless, in spite of its probable overestimation of the real N load in the effluent, and of the related possible N_2O emissions, it lies within the range allowed by the uncertainties.

Alternative data sources for the average protein intake per person and day include:

- The 1991 food table for practical applications (Senser and Scherz 1991) gives an average protein intake of 94 g/inhabitant and day.
- The nutrition report of the German Nutrition Association (Deutsche Gesellschaft für Ernährung) (DGE 2008a, b)[135] used estimated food-consumption data for 2005/2006 to estimate average daily protein intake. From that data, an average value of about 79 g protein / person and day[136] was derived.

The FAO database in the (FAO 2006) Statistical Yearbooks 2004 (Vol.1/1), 2007–2008 and 2010 (table D.1) is used as a basis for determination of N_2O emissions from wastewater, since

[133] With respect to the annual wastewater quantities determined by the DWA (municipal wastewater)

[134] With respect to the annual wastewater quantities determined by the Federal Statistical Office (municipal wastewater)

[135] The nutrition report is published every four years.

[136] This value was obtained with the help of the rough estimate that each population group in Germany consists of 50 % men (90.8 g/day) and 50% women (66.7 g/day).

those sources constitute a consistent time series. It is internationally comparable, and it is regularly updated. In addition, the FAO has declared that the new Yearbook for 2007-2008 supplants the previous four FAO yearbook publications. The Federal Environment Agency has no information to the effect that the country-specific values in the food table and in the 2000 nutrition report are more precise or enjoy greater national acceptance. In addition, many countries use the FAO database; as a result, the emissions-determination process used by Germany is internationally comparable. An international comparison shows that the daily protein intake assumed for Germany lies within the middle of the overall range.

The FAO failed to respond to (repeated) enquiries of the Federal Environment Agency (UBA) concerning the FAO's data source in this regard, and the type of quality control and assurance it uses. Those factors are thus unknown to the UBA; neither we, nor the competent authorities, were able to identify the FAO's national data supplier.

7.5.1.3.5 Category-specific recalculations (5.D.1 Nitrous oxide from municipal wastewater)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

7.5.1.3.6 Planned improvements (category-specific) (5.D.1 Nitrous oxide from municipal wastewater)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

7.5.2 Industrial wastewater treatment (5.D.2)

7.5.2.1.1 Category description (5.D.2)

Gas	Method used	Source for the activity data	Emission factors used
CO_2	NA	NA	NA
CH_4	D	NS	D/CS
N_2O	CS	NS	CS

The emissions from industrial wastewater treatment are a key category only as a result of their aggregation with municipal wastewater treatment (5.D.1).

The CH_4 emissions reported here relate only to that wastewater fraction that is treated in industrial wastewater treatment facilities. The industrial wastewater fraction that is sent to municipal facilities is included under 5.D.1 (municipal wastewater treatment).

The foundations for calculation of CH_4 emissions from industrial wastewater treatment are described in detail in the underlying research report (AUSTERMANN-HAUN 2014).

In Germany, the biological stage of industrial wastewater treatment is partly aerobic and partly anaerobic. In aerobic treatment of industrial wastewater, as in aerobic treatment of municipal wastewater, no methane emissions occur. On the other hand, digester gas (fermentation gas), consisting largely of CO_2 und CH_4, occurs when organic substances in wastewater are broken down anaerobically.

In Germany today, industrial wastewater is treated anaerobically in many sectors. Such treatment is especially prevalent in the food industry. Data on the relevant plant equipment and systems used in this area are not systematically collected in Germany. On the other hand, an evaluation of AUSTERMANN-HAUN & WITTE (2014a) shows that 184 anaerobically operating facilities are currently in service in Germany, at a total of 136 plants. The plants involved cover a total of 26 industrial sectors, throughout a spectrum that includes such diverse areas as vegetable processing, sugar production, paper production and production of cleansers. The largest COD loads that are treated anaerobically occur in pulp and paper production, sugar production and the breweries sector.

The systems used for anaerobic industrial wastewater treatment especially include sludge-bed reactors (upflow anaerobic sludge blanket (UASB) and expanded granular sludge bed (EGSB) reactors). Anaerobic activated sludge processes are also used. All relevant facilities are equipped with gas flares with automatic ignition, as required by law. Only one plant, a relatively small sugar plant, treats its wastewater in anaerobic ponds.

Almost all of the resulting digester gas is collected and combusted either to provide process heat (where it replaces town gas) or to generate electricity. Use for energy recovery is reported under CRF 1.A.1.

The only CH_4 emissions that are relevant for Germany, therefore, are those that occur via unintended releases. Such unintended releases can include:

- CH_4 in the liquid-phase effluent of methane reactors (the relevant quantities are temperature-dependent),
- Losses from gas-storage systems,
- Losses via sludge removed from systems for storage of anaerobically granulated sludge,
- Gas that forms in non-aerated pond systems,
- Gas that forms in acidification reactors,
- Gas that forms in wastewater ponds of the sugar industry,
- Losses via leaks/malfunctions/flaring losses.

All of the gas flares used with relevant gas-collection systems are emergency/shutdown flares; i.e. they also come into play when systems (such as combined heat-and-power (CHP) generating systems) have to be shut down for maintenance purposes. Such gas flares are designed to be able, in emergencies, to burn all of the gas being collected. The gas quantities routed through gas flares are not recorded. However, since the flares are used only as emergency flares, the gas quantities burned during normal system operation are nearly zero. Gas flares are equipped with automatic ignition systems that assure reliable burning of collected gas during disruptions of normal system operation. For this reason, the methane emissions from gas flares are assessed by experts as "zero".

According to experts (AUSTERMANN-HAUN 2014), in the area of anaerobic industrial wastewater treatment, two malfunctions involving gas losses have occurred in Germany in recent decades as a release of leakage from methane reactors' gas-containment vessels. As a result of the odour emissions that accompany them, such leaks are quickly discovered, located and eliminated. In 1992, odour emissions at a wastewater treatment plant led to the discovery of a leak in a methane reactor's glass-fibre reinforced plastic (GRP) roof. A second case of leakage occurred in 2013, in the steel roof of a methane reactor. As a result of the small number of such malfunctions (2 in a total of 30 years of operation of a pool of methane reactors that now numbers 184), the methane emissions from malfunctions involving leakage are classified as negligible.

Other types of malfunctions – for example, malfunctions that inhibit the methane bacteria – do not result in any methane emissions.

7.5.2.1.2 Methodological issues (5.D.2)

Annual COD loads were calculated for 20 of the 26 relevant industrial sectors, using the formula below (Equation 6.6, 2006 IPCC Guidelines). To that end, the applicable production quantities for 2013, and the applicable specific wastewater production as given in federal statistics (FEDERAL STATISTICAL OFFICE (STATISTISCHES BUNDESAMT), Fachserie 4 Reihe 3.1), were determined for each industrial sector and then combined with the relevant specific COD concentrations in the raw wastewater given in the research report. For 6 industrial sectors, it was not possible to calculate the annual COD load, because the literature provided no data on the sectors' specific wastewater production.

$$TOW_i = P_i \cdot W_i \cdot COD_i$$

Where

TOW_i	= total organically degradable material in the wastewater of industrial sector i (annual COD load), in kg COD / year
i	= industrial sector
P_i	= total annual production in industrial sector i, in t / year
W_i	= specific wastewater production in industrial sector i, in m³/t$_{product}$
COD_i	= chemical oxygen demand (degradable organic components in industrial wastewater), in kg COD/m³

Since it is good practice to calculate with country-specific data, and since country-specific data area available for Germany, we use our own method for calculation of total methane emissions, rather than the IPCC method (Equation 6.4, IPCC 2006). The total methane emissions from industrial wastewater treatment are calculated with the following formula:

$$CH_4\ Emissions = \sum_i \left[\left(TOW_i \cdot \omega_{ANR,i} \cdot \omega_{CSB,i} \cdot EF_{CH4,gelöst,i} \right) + E_{CH4,GS,i} + E_{CH4,PS,i} + E_{CH4,AT,i} \right]$$

where:

$CH_4\ Emissions$	= CH_4 emissions in the inventory year, in kg CH_4 / year
TOW_i	= total organically degradable material in the wastewater of industrial sector i (annual COD load), in kg COD / year
i	= industrial sector
$\omega_{ANR,i}$	= percentage share of anaerobic treatment, for industrial sector i
$\omega_{CSB,i}$	= degree of COD degradation in anaerobic treatment, for industrial sector i
$EF_{CH4,dissolved,i}$	= emission factor for CH_4 dissolved in water, in industrial sector i, in kg CH_4 / kg $COD_{removed}$
$E_{CH4,GS,i}$	= CH_4 emissions from gas-storage systems in industrial sector i, in kg CH_4 / year
$E_{CH4,PS,i}$	= CH_4 emissions from systems for storage of anaerobically granulated sludge in industrial sector i, in kg CH_4 / year
$E_{CH4,AT,i}$	= CH_4 emissions from wastewater ponds in industrial sector i, in kg CH_4 / year

The specific emission factors $EF_{CH4,dissolved,i}$ for methane dissolved in the water phase have been calculated on the basis of Henry's law, and they are listed in the research report.

The emissions from gas-storage systems are based on the permissible rates of leakage from such storage systems. On this basis, the CH_4 emissions per gas-storage system have been calculated as 20 m³ CH_4 / year.

The emissions from systems for storage of anaerobically granulated sludge have been set at 0 kg CH_{4b} / year, since the emissions from this area are considered to be negligible (expert assessment). Similarly, the CH_4 emissions from malfunctions have been set at 0 kg CH_4 / year.

The methane emissions from acidification reactors are negligible, as a result of such reactors' unfavourable conditions for methane formation, and have been set at 0 kg CH_4 / year.

The emission factor for emissions from wastewater ponds has been determined in keeping with Formula 6.5 and Table 6.8 in IPCC 2006. For Bo, the IPCC default value has been used; for the MCF, 0.2 has been used, for a pond depth of no more than 2 metres.

All in all, with the formula given above, methane emissions of **1.66 Gg CH_4 / year** from industrial wastewater treatment have been calculated **for the year 2013**.

The time series for the period as of 1990 was obtained on the basis of trends in anaerobic industrial wastewater treatment – especially with regard to capacities for treatment of COD loads. The report year 2013 is considered to represent the current maximum for CH_4 emissions from industrial wastewater treatment (= 100 %), since anaerobic-treatment capacities were expanded more or less continually until that year. The following Table 338 shows the relevant treatment capacities for the years 1990 through 2013, relative to the reference year 2013. The treatment capacities added or decommissioned were taken into account for each of the years involved.

Table 338: Time series for CH_4 emissions from industrial wastewater treatment

Year	Percentage with respect to the CH_4 emissions of 2013	CH_4 emissions [kg CH_4 / year]
1990	22 %	370,087
1991	25 %	412,586
1992	28 %	466,675
1993	32 %	531,381
1994	35 %	578,828
1995	37 %	620,829
1996	40 %	670,093
1997	42 %	687,760
1998	46 %	757,438
1999	47 %	781,860
2000	56 %	919,931
2001	63 %	1,037,566
2002	65 %	1,082,665
2003	70 %	1,164,154
2004	75 %	1,249,558
2005	84 %	1,387,979
2006	88 %	1,455,251
2007	89 %	1,479,197
2008	93 %	1,539,009
2009	95 %	1,572,347
2010	96 %	1,593,094
2011	99 %	1,643,412
2012	100 %	1,653,610
2013	100 %	1,657,206

7.5.2.1.3 Uncertainties and time-series consistency (5.D.2)

The data for annual production quantities were obtained from surveys of the Federal Statistical Office (STATISTISCHES BUNDESAMT, Fachserie 4 Reihe 3.1) and thus are considered to be reliable. On the other hand, some production-quantity data are subject to confidentiality requirements. This can be the case, for example, when only a small number of producers produce a given product. For this reason, the uncertainty for the production-quantity data is given as ± 5 %.

Experts put the uncertainty for the total methane emissions at ± 50 %. The reasons for this include a lack of data for some industrial sectors, differences between methane reactors' operational pressures, differences between the membranes used in gas-storage systems and that fact that it is not known how many gas-storage systems are in service.

7.5.2.1.4 Category-specific quality assurance / control and verification (5.D.2)

General quality control, and quality assurance in conformance with the requirements of the QSE manual and its associated applicable documents, have been carried out.

The data cannot be cross-checked against ETS data, since the described installations are not subject to emissions trading requirements.

7.5.2.1.5 Category-specific recalculations (5.D.2)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

7.5.2.1.6 Planned improvements (category-specific) (5.D.2)

No further improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

7.5.2.2 Nitrous oxide emissions from industrial wastewater treatment (5.D.2)

7.5.2.2.1 Category description (5.D.2 N_2O, industrial)

Nitrous oxide emissions can occur as a by-product of biological wastewater treatment with added nitrogen elimination. They occur mainly in connection with denitrification, although they are presumed to occur also in connection with nitrification. Presumably, in such treatment, reduction from N_2O to N_2 is hindered by various influencing factors, such as free oxygen, high concentrations of nitrite, ammonium and/or sulphides, and such hindrance leads to the formation of N_2O.

For estimation of N_2O emissions from municipal wastewater treatment (5.D.2), the pertinent N_2O emission factors are determined on the basis of the average per-capita (i.e. per-inhabitant) protein intake. As a result, industrial wastewater may be considered completely separately. Since all wastewater in Germany undergoes biological treatment, the site at which industrial wastewater is treated – in a facility at the operational site or in a municipal wastewater treatment plant – is not an important factor to consider.

7.5.2.2.2 Methodological issues (5.D.2 N_2O, industrial)

For determination of nitrous oxide emissions from industrial wastewater treatment, a research project collected data on product-specific wastewater production, on nitrogen concentrations and on COD (chemical oxygen demand) for all industrial areas and then, on the basis of annual production figures, determined annual nitrogen loads. The underlying data on nitrogen loads have been obtained from information sheets of the DWA (Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e. V.). They reflect the current, recognised state of scientific research. The relevant procedure is set forth in detail in UBA 2011b. A COD:N ratio < 40 served as the threshold criterion for assuming that the wastewater of a given sector had a nitrogen surplus that would be able to cause nitrous oxide emissions in subsequent biological wastewater treatment. A possibility that nitrous oxide could be emitted in biological wastewater treatment can be assumed only if the wastewater contains so much nitrogen that, after conversion into biomass, a residual amount of nitrogen remains that has to be removed via biological nitrogen elimination. The value used has been verified by the document ATV-DVKK-Arbeitsblatt A 131 which, as a simplification, considers the nitrogen load to amount to 2 to 2.5 % of the COD concentration (2.5 % is equivalent to a COD:N ratio of 40:1). The data compilation made it possible to identify the 6 industrial sectors that are most important in this regard. Together, those sectors account for some 75 % of the nitrogen load from industrial wastewater treatment (UBA 2001b). These include:

- Slaughterhouse and meat-processing operations,
- Milk processing,
- Processing of animal by-products,
- Beer production,
- Sugar production,
- Wheat starch production.

Data for the textile industry (7.5 % of the total nitrogen load) and for potato processing (2.6 % of the total nitrogen load) have not been included, since the wastewater from those areas has a COD:N ratio greater than 40 and thus, according to the findings of the research report, does not lead to formation of nitrous oxide. Production of potato starch is not considered relevant with regard to formation of nitrous oxide – that area accounts for less than 0.4 % of the total nitrogen load in wastewater.

The annual nitrogen load that is discharged into raw wastewater was determined on the basis of the mean product-specific nitrogen loads for the 6 aforementioned industrial sectors, as well as of the pertinent annual production figures. In the process, it is assumed that, as a result of organisational and technical measures, such discharges were gradually reduced to the level seen in 2010, and that the nitrogen quantity discharged into wastewater in 1990 was 30 % higher than that level (expert estimate). For the years 1990 through 2000, annual nitrogen-load reductions of 2 percentage points are assumed, while one-percent reductions are assumed for the period 2000 through 2010 (expert estimate). As of 2010, the nitrogen load per cubic metre of wastewater is assumed to be constant (expert estimate).

The activity-data calculation was carried out as follows:

$$AD = \sum_B [NF_B \times PZ_B \times 10^{-6}]$$

Where

AD	= total activity data [t N_Z / year] = average N load in the inflow = N_Z
NF_B	= average specific N load for the relevent sector [g N per unit]

PZ_B = production figures for the year 2010, for the relevant sector [number of units / year]
10^{-6} = factor for conversion of g into t

The N_2O emission factor was determined, in the aforementioned research project, by analysing various data from the literature. From those data, a weighted mean value was formed. As a result, it was found that 1 % of the nitrogen load in the inflow for a wastewater treatment plant is emitted as N_2O-N.

$$N_2O = EF \times AD \times 44/28$$

Where

N_2O = N_2O emissions in t N_2O / year
EF = emission factor of 0.01 t N_2O-N / t N
44/28 = stoichiometric factor for conversion of N_2O-N to N_2O

7.5.2.2.3 Uncertainties and time-series consistency (5.D.2 N_2O, industrial)

The uncertainties in the production figures originate in the relevant Federal statistics, and other statistics, all of which are based on exhaustive surveys. The uncertainties for the data are thus likely to be very low.

In the aforementioned research project, the N_2O emission factor was determined (by expert estimate) to have a very high uncertainty of - 100 % / + 300 %.

The mean specific nitrogen loads in the various relevant sectors have the uncertainties shown in (Table 339). The uncertainties were determined via expert estimates. In a conservative estimate, the uncertainty for the total nitrogen load (activity data) is assumed to be -50 % / +50 % (expert estimate)

Table 339: Uncertainties for the mean specific nitrogen loads for the 4 industrial sectors that are most important in this regard

Mean spec. N load of the industrial sector	Uncertainty, upper bound	Uncertainty, lower bound
Slaughtering of swine	40	40
Slaughtering of sheep	50	50
Slaughtering of goats	50	50
Slaughtering of cattle	40	40
Slaughtering of horses	50	50
Slaughtering of poultry	40	40
Meat processing	40	40
Processing of animal by-products	20	20
Milk processing	15	15
Beer production	30	30
Sugar production	30	30
Wheat-starch production	30	30

7.5.2.2.4 Category-specific quality assurance / control and verification (5.D.2, N_2O industrial)

General quality control, and quality assurance in conformance with the requirements of the QSE manual and its associated applicable documents, have been carried out.

The data cannot be cross-checked against ETS data, since the described installations are not subject to emissions trading requirements. The described activity data have been obtained from the public statistics of the Federal Statistical Office, with the exception of the data for processing of animal by-products; those data have been taken from the report of the

"Servicegesellschaft tierische Nebenprodukte". No further activity data of relevance for plausibility checking are available at present.

For purposes of plausibility checking, an attempt was made to consult comparable data from the inventory reports of other countries. In the Netherlands and in Austria, N_2O emissions from industrial wastewater treatment have been classified as irrelevant, and thus those countries provided no basis for comparison. A study of the literature on nitrous oxide emissions from wastewater treatment was carried out in [UBA 2011b]. The emission factors used in the present context have been derived from that study. They agree with IPCC 2006c, pursuant to which 0.5 percent (0.05 – 25 percent) of the nitrogen load is converted to nitrous oxide. No other emission factors are available.

7.5.2.2.5 Source-category-specific recalculations (5.D.2 N_2O, industrial)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

7.5.2.2.6 Planned improvements (category-specific) (5.D.2 N_2O, industrial)

No improvements are planned at present.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

7.6 Other sectors (5.E Other)

Currently, only emissions from mechanical biological waste treatment are being reported in category 5.E.

KC	Category	Activity	EM of	1990 (kt CO_2-e.)	(fraction)	2013 (kt CO_2-e.)	(fraction)	Trend 1990-2013
-/-	5.E Other	Other	N2O	0,0	(0,00%)	127,1	(0,01%)	-
-/-	5.E Other	Other	CH4	0,0	(0,00%)	5,9	(0,00%)	-

The category *Other* (5.E) is no key category.

7.6.1 Other areas – mechanical biological waste treatment (MBT) (5.E Other MBT)

7.6.1.1 Category description (5.E Other MBT)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	CS	NS	CS
N_2O	CS	NS	CS

As of 1 June 2005, direct landfilling of organic and biodegradable waste is no longer permitted in Germany. Miscellaneous settlement waste, and other waste of similar composition, may thus be landfilled only following pre-treatment. In addition to thermal waste-treatment processes (waste incineration), mechanical biological processes are increasingly being used for this purpose.

Since the 1990s, mechanical biological processes have been used extensively in Germany for managing miscellaneous waste. Initially, relevant plants had relatively simple designs and were not fitted for waste-gas collection and treatment. As processes have improved, however, closed systems, with "biofilters" for waste-gas scrubbing, have gradually become the norm. While the waste-gas-scrubbing processes used by such plants have significantly reduced the plants' smell emissions, they have not reduced greenhouse-gas emissions.

In 2005, when all landfilling of untreated waste was terminated, capacities for mechanical biological waste treatment were considerably expanded. Pursuant to the 30th Ordinance on the Execution of the Federal Immission Control Act (30th BImSchV), as of 1 March 2001, new plants for mechanical biological waste treatment must fulfil strict technical requirements and conform to demanding standards for maximum permitted emissions. The transitional provisions for old plants call for such plants to be retroffited by no later than 1 March 2006.

Nearly all recently constructed new facilities were commissioned in 2005. Via expansions and operational upgrades, nearly all old facilities were brought into conformance with the 30th BImSchV by 2005. The transitional situation prevailing in 2005 can hardly be described with existing calculation models, since the relevant waste quantities cannot be correlated with the various relevant facility technologies. For the sake of simplicity, emissions through the year 2005 are calculated with the higher emission factors applying to the older-facility systems. For 2006, emissions are being calculated using the lower emission factors for the new facilities.

Currently, about 4.5 million Mg of waste are treated annually in mechanical biological waste treatment plants. This produces about 0.5 million Mg of treatment residues that have to be landfilled. In addition, about 2.5 million Mg of waste fractions with high calorific values are separated out and then used as substitute fuels in industrial combustion systems. The metals contained in the waste are separated out and used as secondary raw materials. The remainder of 1.5 million Mg consists of mass losses, in the treatment process, occurring via biodegradation of organic fractions and evaporation or drainage (wastewater) of the water in the waste.

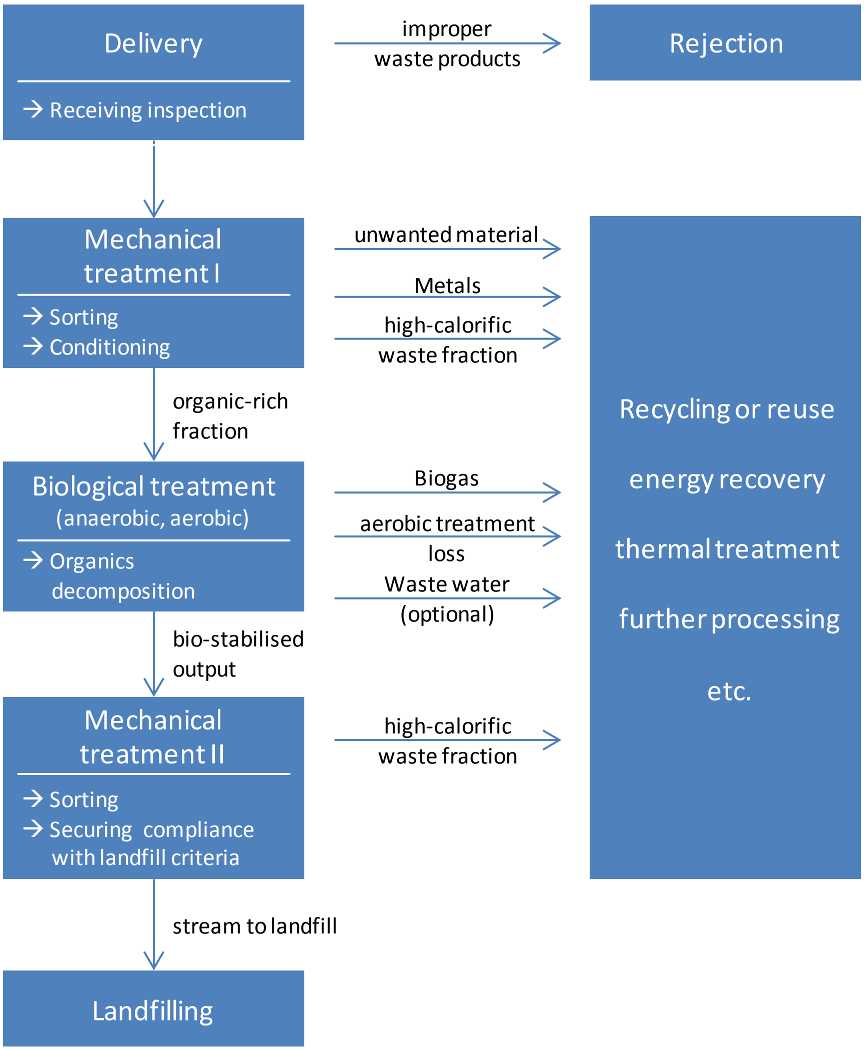

Figure 80: Substance-flow scheme for mechanical biological waste treatment (MBT)[137]

7.6.1.2 Methodological aspects (5.E Other MBT)

Since 1995, the Federal Statistical Office has regularly collected and published data on waste quantities managed in MBT systems. For the period 2007 through 2010, recent reports have used data from the research project "Facilities for mechanical and biological treatment of residual waste" ("Anlagen zur mechanisch-biologischen Restabfallbehandlung") (UBA, 2007). In connection with those earlier reports, there was doubt as to whether the data of the *Federal Statistical Office* cover all types of facilities that, in terms of their emissions behaviour, must be grouped with MBT facilities. As a conservative approach therefore, emissions calculation was carried out using the higher waste quantities determined by the research project. Via a number of discussions with the Federal Statistical Office, those doubts have since been eliminated. For the years 2007 through 2010, the 2014 NIR included a recalculation carried out with data of the Federal Statistical Office (Statistisches Bundesamt, Fachserie 19, Reihe 1 of 12 July 2012). For further reporting, the current data of the Federal Statistical Office are used.

[137] Source: VDI 3475 Blatt 3, Emisssionsminderung - Anlagen zur mechanisch-biologischen Behandlung von Siedlungsabfällen, 2006-12 (amended)

Activity data

Since 1995, the Federal Statistical Office has regularly collected and published data on waste quantities managed in MBT systems.

Emission factors

In the 1990s, emissions from mechanical biological waste treatment were studied in a major collaborative research project supported by the Federal Ministry of Education and Research (BMBF). In a project carried out in 2003, the Institute for Energy and Environmental Research (IFEU) used the collaborative research project's findings to develop emission factors. In doing so, it differentiated between mechanical biological waste-treatment processes that were open (with no waste-gas collection and treatment) and processes that were closed (with waste-gas collection and treatment in biofilters). For methane, the emission factors for both types of processes were considered to be the same, since that substance is hardly broken down at all in biofilters. The N_2O emission factor for closed systems was considered to be higher than that for open systems, since N_2O also forms in biofilters, via oxidation of ammoniacal nitrogen.

Since June 2005, as a result of new legal provisions (30th BImSchV), all mechanical biological waste-treatment facilities are closed facilities, which have the more effective waste-gas-scrubbing processes. As of 2006, therefore, the emissions standards of the 30th BImSchV are used as the emission factors.

For open mechanical biological waste-treatment facilities, the following emission factors resulted:

EF-N_2O = 190 g N_2O/Mg waste
EF-CH_4 = 150 g CH_4/Mg waste

For closed mechanical biological waste-treatment facilities with biofilters, the same study obtained the following emission factors:

EF-N_2O = 375 g N_2O/Mg waste
EF-CH_4 = 150 g CH_4/Mg waste

For the period as of 2006, the emissions-load limitations imposed by the 30th BImSchV will be used as the applicable emission factors:

EF-N_2O = 100 g N_2O/Mg waste
EF-CH_4 = 55 g CH_4/Mg waste

All German MBT facilities reliably conform with those emissions standards, and in some cases their emissions are even considerably lower. Since in 2005 most MBT systems were equipped with waste-gas-treatment systems for minimising N_2O emissions, the emission factor for 2005 was estimated to be 169 g.

These national emission factors were used for the inventory calculations.

7.6.1.3 Uncertainties and time-series consistency (5.E Other MBT)

The uncertainties for the mechanically-biologically treated waste quantities are considered to be very small (2 %) theoretically, since the relevant data were obtained via a complete-coverage survey, the reporting quality is good and operators have an interest in quality reporting. Nonetheless, it will be necessary, in order to rule out any possibility of underestimation of waste quantities, to consult with the Federal Statistical Office to determine which versions of "cold" waste-treatment processes are assigned to the MBT category. The uncertainties for the emission factors are high for the period before 2005. They depend on the type of facility/plant in question, on the type of process used at the relevant time and on the effectiveness of the biofilters used. The pertinent figures from the literature vary widely. For the period after 2005, it may be assumed that emissions easily comply with the standards of the 30th BImSchV or are even much lower than those standards. The only uncertainties are found in the question of the extent to which emissions during actual plant operations lie below the standards.

7.6.1.4 Category-specific quality assurance / control and verification (5.E Other MBT)

General quality control, and quality assurance in conformance with the requirements of the QSE manual and its associated applicable documents, have been carried out.

7.6.1.5 Category-specific recalculations (5.E Other MBT)

This year, as explained in Chapter 8, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

As the NIR 2014 was being prepared, statistical data on landfilled waste quantities were available only up to 2012. The quantities of waste treated were thus considered to have remained constant in 2013 and 2012. Therefore, the emissions of the year 2012 were recalculated with the current data published in Fachserie 19 Reihe 1 of 29 July 2014.

7.6.1.6 Planned improvements (category-specific) (5.E Other MBT)

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

8 OTHER (CRF SECTOR 7)

At present, no greenhouse gas emissions are calculated for Germany which cannot be allocated to one of the existing categories.

9 INDIRECT CO_2 & NO_X

Germany does not report any emissions for indirect NO_X, and for indirect CO_2 it reports only NMVOC emissions from solvent use. These NMVOC emissions are determined for information purposes. For details on how they are converted into indirect CO_2, we refer to the sections on non-energy-related products from fuels and solvents in Chapter 4.5.3, *Other, solvents – NMVOC*.

10 RECALCULATIONS AND IMPROVEMENTS

Chapter of the *2006 IPCC Guidelines* provides detailed descriptions of the reasons and conditions that, either singly or in combination, can lead to the need for recalculations of inventory calculations. Normally, such reasons and conditions are compiled and analysed in this section. Further information regarding the recalculations is provided in CRF Table 8(a) and Table 8(b) and in the present report's chapters on category-specific recalculations.

Recalculations in the 2015 inventory

The present 2015 Submission has a special status, however, in many regards, that precludes any justification, or qualitative and quantitative description, of the recalculations carried out in the various categories.

This status results in that the present submission is the first submission…

- in the framework of the second commitment period of the Kyoto Protocol
- in keeping with the 2006 IPCC Guidelines
- in keeping with the new UNFCCC CRF structure
- to use the *Global Warming Potentials* (GWPs) introduced with the IPCC's Fourth Assessment Report

This status also entails the need to *include greenhouse gases and emission sources not previously included*.

Due to the lack of a comparable previous year's report, i.e. a report prepared within a comparable framework, we refrain from providing a detailed consideration here of the recalculations that have been carried out.

Furthermore, the CRF Tables 8(a) and (b), which list the information on category-specific recalculations provided either in the present section or in the various chapters, have not been completed for the present submission.

The customary detailed presentation of the reasons for, and consequences of, the relevant recalculations will again be provided in the next report.

10.1 Procedure for KP-LULUCF Inventory

This year, as explained above, the methodological changes required pursuant to decision 24/CP.19 are being applied for the first time, and, as a result, no comprehensive detailed documentation and quantification of the effects of recalculations are being provided.

Because the IPCC KP Supplements (IPCC 2014) and the IPCC 2006 Guidelines (IPCC 2006) have been implemented in this year's submission, a complete recalculation of the inventory, and of all category-specific time series for the first year (2013) of the second commitment period of the Kyoto Protocol, was carried out on the basis of these provisions.

In this year's submission, cropland management and grazing land management are being reported for the first time.

10.2 Inventory improvements

10.2.1 Greenhouse-gas inventory

The following table summarises the improvements made in GHG-emissions reporting on the basis of the ERT's references and remarks in past reviews under the UN Framework Convention on Climate Change and the Kyoto Protocol. The table lists only aspects that were not already successfully addressed during the Review.

Table 340: Compilation of the Review recommendations successfully addressed as of the current report

CRF	Review Findings	Improvement	Report [year]	Source	Reference
0.	The ERT commends the Party for summarizing the planned improvements but reiterates the previous recommendation that Germany also provide, in its next NIR, a plan outlining how and when it itends to implement the identified areas for improvements	see chapter 10.4.1	2011	ARR	§ 30
1.A.	NIR section 3.2.1.2.1 includes an appropriate comparison with the IEA emission calculations. The text notes that annual deviations between the sectoral approach of IEA and the national, detailed method vary throughout the time series from –2.8 to 2.9 per cent. The NIR also states that the "average deviation for (currently) 20 years is 0.4 per cent". The ERT noted that, in statistics, the average deviation is based on the absolute rather than the real values of individual deviation figures, because the average of a set of numbers with a similar range of values above and below zero will be close to zero. The ERT encourages Germany to modify the way it calculates the average deviation, in order to conform with statistical convention, for its next annual submission.	Correction of mathematic failure	2012	ARR	§ 42
1.A.2.a.	The ERT has identified several large inter-annual changes in the CH4 IEF for the subcategory iron and steel, including from 0.72 kg/TJ in 2002 to 5.44 kg/TJ in 2003 (increase of 652.7 per cent) and from 2.78 kg/TJ in 2008 to 0.86 kg/TJ in 2009 (decrease of 69.2 per cent). In response to a question raised by the ERT during the review, Germany explained that the fuel category gaseous fuels includes both natural gas and pit gas. Natural gas is mostly used in boilers and power plants, mixed with blast furnace gas, oxygen furnace gas and coke oven gas. Pit gas is burned in engines with considerably higher CH4 emissions. The relationship between the two fuel types changes every year, mainly due to the availability of pit gas. The ERT recommends that Germany provide a brief explanation of this issue in its NIR to increase transparency.	Subcategory is irrelevant compared to the total of category emissions. An explanation of the inter-annual changes of the IEF can be given on request, but yearly revision of the trend is exceeding the entitys resources.	2013	ARR	§ 36
1.A.3.d.(b)	Emissions from domestic navigation are calculated using AD from the NEB. During the review week, the ERT received information from the Party that international transport on inland waterways (e.g. on the Rhine) is included in the domestic navigation emission estimate. This is not in line with the IPCC good practice guidance and is a potential overestimation of emissions. The ERT recommends that emissions from international navigation activities be attributed to memo items under international bunker fuels.	Issue has been resolved	2010	ARR	§ 73
1.A.4.	The CH4 IEF for solid fuels in the subcategory commercial/institutional has a decreasing trend: from 239.90 kg/TJ in 1990 to 108.91 kg/TJ in 2011 (–54.6 per cent). In 2011 the CH4 IEF was considerably higher than the IPCC default value (10.0 kg/TJ), and third highest among the reporting Parties (range from 0.071 to 427.34 kg/TJ). In response to a question raised by the ERT during the review, Germany explained that a country- specific EF for CH4 has been derived from measurement values and it can be explained by a relatively large share of small appliances with high CH4 emissions. The ERT recommends that Germany provide a brief explanation of this issue in its NIR to improve transparency.	Subcategory is irrelevant compared to the total of category emissions. An explanation of the inter-annual changes of the IEF can be given on request, but yearly revision of the trend is exceeding the entitys resources.	2013	ARR	§ 35
1.B.1.	According to the NIR (page 228), for German soft lignite, the temperature does not exceed 50 °C during the coalification processes, while significant CH4 releases occur only at temperatures above 80 °C (based on the results of a national study, (Ziegler et al., 1992)). From the NIR only, the ERT could not verify the low CH4 EF used. During the review Germany presented underlying information from the study and the ERT believes that the figures are applicable to Germany. The ERT encourages the Party to verify that the EF is still valid for later years and to improve the justification for the use of the country-specific EF within the NIR.		2011	ARR	§ 51
1.B.2.b	The CH4 emissions from natural gas production/processing increased by 17.8 per cent from 2007 to 2008 (from 2.93 Gg to 3.46 Gg) and by 11.2 per cent from 2008 to 2009 (3.84 Gg). From 2009 to 2010 (2.21 Gg) the emissions decreased by 42.4 per cent. In response to a question raised in the previous stages of the review, Germany explained that the amount of gas produced and thus also emissions have generally a decreasing trend. According to the German association of the oil and gas industry (Wirtschaftsverband Erdöl- und Erdgasgewinnung e.V.) the production plants were optimized in the years 2008–2009, which led to higher emissions in those years. Germany further stated that the variance between the yearly emission amounts is within the specified range of the uncertainty (NIR chapter 3.3.2.4.2.3). The ERT recommends that Germany provide an explanation of this issue in the NIR and ensure that the reasons for such fluctuations are appropriately reported in the NIR.	Germany already stated that the variance between the yearly emission amounts is within the specified range of the uncertainty .	2013	ARR	§ 33

CRF	Review Findings	Improvement	Report [year]	Source	Reference
1.B.2.b	The CH_4 emissions from natural gas transmission increased by 19.6 per cent from 2008 (14.01 Gg) to 2009 (16.75 Gg) and decreased by 4.8 per cent from 2009 to 2010 (15.95 Gg). In response to a question raised by the ERT during the previous stages of the review, Germany explained that the volume of gas stored in reservoirs in 2009 was higher than usual, and also the reported length of steel pipeline was higher than in the years before or after 2009. Germany explained that neither the association of the oil and gas industry nor UBA can provide a reasonable explanation for these anomalies. In an attempt to avoid underestimation, Germany estimated emissions using the pipeline length reported for 2009 instead of interpolation. The Party also explained that the uncertainty of this subcategory is 20 per cent. The ERT encourages Germany to investigate this variance and report on it in the NIR.	Germany already stated that the variance between the yearly emission amounts is within the specified range of the uncertainty .	2013	ARR	§ 34
1.D.1.b.	The ERT appreciated this clarification and noted the difficulty in obtaining data to separate the emissions, but encourages Germany to find a way to separate the emissions from inland navigation activities and report emissions from international navigation activities as a memo item under domestic and international emissions bunker fuels by making appropriate assumptions, and to clearly describe them in the NIR.	Issue has been resolved	2011	ARR	§ 46
1.D.1.b.	Consistent with recommendations in the previous review report, the ERT noted that Germany continues to be unable to distinguish the amount of bunker fuel that is used for international transport on inland waterways (such as on the Rhine river) from that used for domestic navigation. The ERT also noted that this leads to a potential overestimation of emissions. Taking into consideration the small contribution of the category to the national totals, the ERT suggests that Germany make efforts to separate the emissions from international transport associated with inland navigation from the emissions from domestic navigation, taking into account the availability of resources.	Issue has been resolved	2012	ARR	§ 50
1.D.1.b.	The ERT noted that due to lack of usable AD, Germany cannot distinguish the small amount of bunker fuel that is used for international transport on inland waterways (such as on the Rhine river) from that used for domestic navigation, as indicated in the previous review reports. The ERT also noted that the approach of Germany leads to a potential slight overestimation of emissions from navigation. Taking into consideration the small contribution of the category to the national totals, the ERT encourages Germany to make efforts to separate the emissions from international transport associated with inland navigation from the emissions from domestic navigation, taking into account the availability of resources.	Issue has been resolved.	2013	ARR	§ 38
2.	The methods and data used to calculate emissions, as well as category-specific information on uncertainties and QA/QC, are explained for each category in the NIR, although the details are not always transparently presented, especially because of the confidentiality of many AD. This issue has made it difficult for the ERT to review the inventory. In particular, CRF table 8(b) for 2009 does not provide explanatory information for the recalculations of PFCs from aluminium production. The ERT noted the lack of consistency in the information presented in different sections of the NIR for some recalculations (e.g. the descriptions of the recalculation for ferroalloys production in sections 4.4.2.5 and 10.1.1.2 of the NIR, for aluminium production between sections 4.4.3.5 and 10.1.1.2 of the NIR, and for ferroalloys production between sections 4.4.2.5 and 10.1.1.2 of the NIR). The ERT recommends that the Party improve the transparency of its reporting by providing information on all undertaken recalculations in CRF table 8(b) in its next annual submission and improve the consistency of the information presented in its NIR.	Issue cannot be resolved entirely. This is due to the fact, that there are a lot of recalculations that are of such a minor effects, that they cannot be reasonably and completely addressed in the NIR. That's why they are addressed on aggregated level only, whereas CRF table 8(b) is complete. That's the only reason for the differences.	2012	ARR	§ 55
2.	In response to the recommendation in the previous review report regarding the use of data collected under the EU ETS for the verification of emission data in the industrial processes sector, Germany started a research project in December 2010 focusing on data exchange between the EU ETS and national GHG reporting. The procedure is described in section 1.3.3.1.7 of the NIR. The ERT commends Germany for this effort. However, the results of the verifications made prior to the 2012 annual submission are not well described in the NIR. During the review, in response to a question raised by the ERT, the Party submitted the results from the verification of lime production and stated that emissions from glass production have also been verified, as described in the NIR. The ERT recommends that Germany report on the progress of this project and the implications that the project has had on the QA/QC procedures and present the results of the verification in its next annual submission.	Project has been finished, which is documented in the NIR.	2012	ARR	§ 56 + § 59
2.	The NIR and the CRF tables are generally transparent. The notation key "IE" (included elsewhere) is used in the industrial processes sector to report CO_2 emissions from limestone and dolomite use and from ceramic production (a country-specific subcategory under other (mineral products)), CO_2 and CH_4 from pig iron, coke and sinter, and N_2O from medical use (country-specific subcategory under other (chemical industry)). In the solvent and other product use sector, emissions from aerosol cans are reported as "IE". The Party has explained under which categories the emissions are reported, but the ERT encourages the Party to decrease the number of instances where the notation key "IE" is used.	Issue has been checked, but in some cases "IE" remains as the appropriate notation key.	2013	ARR	§ 40

CRF	Review Findings	Improvement	Report [year]	Source	Reference
2.	Not all recalculations mentioned in CRF table 8(b) are explained in the NIR (such as that for SF6 used as trace gas). The ERT reiterates the recommendation made in the previous review report that the Party improve the consistency of the information in CRF table 8(b) with that presented in the NIR.	Issue cannot be resolved entirely. This is due to the fact, that there are a lot of recalculations that are of such a minor effects, that they cannot be reasonably and completely addressed in the NIR. That's why they are addressed on aggregated level only, whereas CRF table 8(b) is complete. That's the only reason for the differences.	2013	ARR	§ 41
2.A. / 2.C.	Germany reports the sum of the following three components under this category: CO2 emissions from use of reducing agents; CO2 emissions from limestone use; CO2 emissions from electrode consumption. This is not in line with the Revised 1996 IPCC Guidelines, according to which CO2 emissions from limestone use in iron and steel production should be reported in the limestone and dolomite use category // ... the ERT reiterates the recommendation in the previous review report to the effect that Germany report CO2 emissions in accordance with the Revised 1996 IPCC Guidelines, or make efforts to do so by giving further analysis and consideration to this issue.	Obsolete, due to entry ino force of the 2006 GL.	2011	ARR	§§ 63, 66
2.A.2	According to the NIR, the German Lime Association collects production data for the entire time series for lime production and the NIR states that this approach ensures that all of German lime production is taken into account in the inventory. Germany has compared the CO2 emissions from lime production with EU ETS emission data for the period 2005–2010. The ERT noted that, for three out of the six years (2006, 2007 and 2010), the CO2 reported in the CRF tables is higher than the CO2 emissions from lime production included in the EU ETS. The description of the category in the NIR of the 2012 annual submission suggests that not all lime production is covered by the EU ETS and, if this is the case, the emissions from lime production in the inventory should be higher than the total emissions for the category under the EU ETS. In response to a question raised by the ERT during the review, the Party explained that the emissions will be recalculated for the next annual submission in the light of the information from the EU ETS. The ERT recommends that the Party justify and transparently describe the estimation methods used, including assumptions made, and how it ensures that the lime production AD are complete. 2013: lfd.Nr 4212	It's checked, but it is not possible to provide EU ETS methodology over three trading periods.	2012	ARR	§ 60
2.A.2	According to the NIR, the German Lime Association collects lime production data for the entire time series and the NIR states that this approach ensures that all German lime production is taken into account in the inventory. Germany recalculated the emissions from lime production in the 2013 annual submission for the entire time series taking into account the default factor of 5.0 per cent impurities in raw materials, which was not included in the emission estimates in the previous annual submission. The recalculation resulted in a 5.0 per cent decrease in the CO2 emissions from the category. The ERT concluded that the method used is in line with the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (hereinafter referred to as the IPCC good practice guidance). In response to questions raised by the ERT during the review, Germany provided a comparison table of CO2 emissions from lime production between the NIR and the EU ETS for 2005–2011. The ERT noted that the CO2 emissions reported in the NIR are lower than those from the EU ETS. The range of differences is from 11.9 per cent in 2005 to 8.9 per cent in 2011. In response to a further question raised by the ERT, the Party explained that at the moment, the correction factor for impurities used for the national GHG inventory calculations cannot be changed from the default value to a value corresponding to EU ETS results due to lack of sufficient knowledge on the issue. The ERT reiterates the recommendation made in the previous review report that Germany analyse the differences between the CO2 emissions reported in the NIR and those from the EU ETS and report on this in the NIR. The ERT further recommends that the Party provide EU ETS methodology and the EFs used to calculate CO2 emissions from lime production in the next annual submission to improve transparency.	It's checked, but it is not possible to provide EU ETS methodology over three trading periods.	2013	ARR	§ 43
2.A.4.d.	The ERT noted that AD and/or GHG emissions are reported as included elsewhere ("IE") for some activities, such as limestone and dolomite use, pig iron and N2O from aerosol cans. Generally, the Party has explained under which categories the emissions are reported, but the ERT encourages the Party to decrease the number of instances where the notation key "IE" is used in the next annual submission.	Closed because "IE" is correct.	2012	ARR	§ 54

CRF	Review Findings	Improvement	Report [year]	Source	Reference
2.A.4.d.	Germany continues to report CO2 emissions from limestone and dolomite use as “IE” and the emissions are included in the categories where limestone and dolomite are consumed (e.g. under iron and steel production or public electricity and heat production (flue gas desulphurization)). However, according to the Revised 1996 IPCC Guidelines, emissions from limestone and dolomite use, except for cement production, lime production and agriculture, are to be reported in the category limestone and dolomite use. The ERT recommends that the Party reallocate CO2 emissions from limestone and dolomite use following the Revised 1996 IPCC Guidelines.	Obsolete, due to entry ino force of the 2006 GL.	2013	ARR	§ 50
2.B.1	During the review week, the Party submitted to the ERT a time series of estimates for recovered CO2 from ammonia production. The ERT encourages the Party to improve the transparency of its reporting by including this time series under ammonia production in its next annual submission.	Done. But due to confidentiallity reasons no further information can be given in the NIR.	2012	ARR	§ 62
2.B.1	According to the NIR, emissions from energy use in ammonia production are reported under the energy sector and the amount of energy used comes from the energy balance. The ERT was not able to extract the amount of energy used for this ammonia production from the energy balance. The Party explained that, in addition to confidentiality concerns, the statistical collection process does not allow for the disaggregation of the energy use between different subcategories of chemical industries. The ERT took note of this explanation and encourages Germany to consider ways to improve the transparency of the NIR while respecting the confidentiality of the data	According to the 2006 IPCC GL the chapter has been revised. Transparency has been improved as far as possible.	2012	ARR	§ 63
2.B.8.a.	The estimated emissions for this category have been subjected to the general QA/QC procedure that is implemented for all categories by the Party. However, the ERT noted that some of the activities in this category are covered by the EU ETS (e.g. burn-off of catalysts at oil refineries, and methanol production), so the ERT recommends that the Party verify the reported emissions using EU ETS data and report the result of the verification in its next annual submission.	Within the actual submission a new method to estimate CO2 emissions in methanol production is used based on ETS data (on plant specific level). One reason for changing the estimation method is to avoid double counting of CO2 emissions in different sectors (energy and IPPU). The CO2 emission values estimated with both methods are not comparable. As the new estimation method uses ETS data a verification with EU ETS data is not applicable.	2012	ARR	§ 67
2.C.1.	The ERT noted that AD and/or GHG emissions are reported as included elsewhere (“IE”) for some activities, such as limestone and dolomite use, pig iron and N2O from aerosol cans. Generally, the Party has explained under which categories the emissions are reported, but the ERT encourages the Party to decrease the number of instances where the notation key “IE” is used in the next annual submission.	use of "ie" is correct and necessary	2012	ARR	§ 54
2.C.1.	Germany reports CO2 emissions from the following three components under this category: use of reducing agents; limestone use; and electrode consumption. This is not in line with the Revised 1996 IPCC Guidelines, according to which CO2 emissions from limestone use in iron and steel production should be reported in the limestone and dolomite use category	Now in line with the IPCC 2006 Guidelines	2012	ARR	§ 68
2.C.1.	In response to questions raised by the ERT during the review, Germany provided important information regarding the difficulties of verifying the inventory data with the EU ETS data that apply to nearly all iron and steel producers that are covered by the EU ETS. The main difficulty arises from the fact that material flows are not available in the German EU ETS data. The EU ETS data are much more aggregated than the inventory data. The Party emphasized that the carbon balance submitted in the NIR underlines the conservative reporting (i.e. possible overestimation of emissions) of the inventory and explained that it plans to intensify the discussions with the iron and steel industry to improve the carbon balance. In relation to Germany’s method for reporting emissions from iron and steel not being in line with the Revised 1996 IPCC Guidelines, the ERT considers that it is important (despite the problem described above) that the Party engage in a dialogue with the industry to identify ways to ensure that the reporting is consistent with the methods in the Revised 1996 IPCC Guidelines (i.e. do not account for emissions from limestone and dolomite use in this category) and that the reported emissions are as accurate and comparable as possible. The ERT strongly recommends that the Party complete this work and report the results in its next annual submission.	Done for all data that can be compared to ETS. For these and those that cannot be compared description is given in the NIR.	2012	ARR	§ 69

CRF	Review Findings	Improvement	Report [year]	Source	Reference
5.D.1.	ERT recommends that Germany improve ist reporting for this category , if CH4 is generated and fully recovered, the quantity recovered should be reported in CRF table 6.B.	The amount of CH4-recovered in category 5.D.1 is given in CRF-Table 5.D	2009	ARR	§101
5.D.2.	The ERT noted that CH4 emissions and recovery for industrial wastewater in CRF table 6.B1 are reported as "NA". The NIR states that industrial wastewater and sludge are partly treated anaerobically and that CH4 produced is collected and used for energy recovery, or flared; thus the treatment of industrial wastewater releases no significant amount of CH4 emissions. In response to the questions raised by the ERT during the review, the Party informed the ERT that it does not currently have sufficient information to justify this; however, the notation key for recovery will be corrected to "IE" because those data are reported in the energy sector under the category manufacturing industries and construction. The ERT reiterates the recommendation in the previous review report that the Party provide, in the next possible annual submission, more details on the treatment of wastewater in the country to sufficiently justify that no CH4 emissions are produced in the process, in order to improve the transparency of its reporting.	Description in the NIR has been further enhanced.	2012	ARR	§ 105
5.D.2.	The Party included in the 2013 annual submission estimates of N2O emissions from industrial wastewater for the first time. The emissions have been estimated based on annual N loads (2.0 to 2.5 per cent of the chemical oxygen demand (COD) concentration) for the four industries that account for 68 per cent of N load from industrial wastewater. The ERT commends Germany for its effort to estimate N2O emissions from industrial wastewater and encourages the Party to determine the COD values for the other industry-specific wastewater streams.	Issue has been resolved. Sugarproduction and WheatStarchproduction have been additionally estimated with the 2015 Reporting. Germany now estimates six industrial branches that account for 75 per cent of N load from industrial wastewater. The Guidelines require only 4 industrial branches.	2013	ARR	§ 70

All measures are aimed at achieving complete consistency with the UNFCCC report guidelines and the IPCC Guidelines and at preventing any adjustments under the Kyoto Protocol.

The following table summarises the information, as provided in the various category chapters of the inventory reports (since 2011), relative to planned improvements. That information is supplemented with details on the resulting needs for action, the planned deadlines for completing the measures and the current processing status in each case.

Table 341: Compilation of a) the planned improvements completed as of the present report and of b) the planned improvements that are mentioned in NIR category chapters and are still pending

CRF-New	Planned improvement	Data quality objective	Deadline	Status	Resolved in NIR-Chapter	Year of Reporting	Reference NIR-Chapter
1.A.2.f.(a)	Fuel allocations to the areas cement, lime and plaster is to be reviewed.	The allocation of fuels used for cement, lime and plaster shall be inspected. The result has to be integrated into the inventory, where appropriate.	[2015]	Closed because not possible to facilitate.		2013	3.2.9.10.6
1.A.2.f.(b)	Fuel allocations to the areas cement, lime and plaster is to be reviewed.	The allocation of fuels used for cement, lime and plaster shall be inspected. The result has to be integrated into the inventory, where appropriate.	[2015]	Closed because not possible to facilitate.		2013	3.2.9.7.6
1.A.3.d.(b)	Currently, the greenhouse-gas inventory for sea transports, including transports between German seaports, is being thoroughly revised. The findings and results from that effort will enter into future reporting on category 1.A.3.d.	Results from revision of the greenhouse-gas inventory relative to sea transports have to be integrated within the inventory.	[2015]	done	3.2.10.4.2	2011	3.2.10.4.6
1.A.3.d.(b)	Currently, the greenhouse-gas inventory for sea transports, including transports between German seaports, is being thoroughly revised. The findings and results from that effort will enter into future reporting on category 1.A.3.d.	Results from revision of the greenhouse-gas inventory relative to sea transports have to be integrated within the inventory.	[2015]	done	3.2.10.4.2	2012	3.2.10.4.6
1.A.4.	The current survey of consumption and emissions of German high-seas fisheries, which is based on a number of highly simplified and conservative assumptions, is to be revised in the medium term.	The assumptions relative to consumption and emissions of German high-seas fisheries have to be revised (cf. the relevant individual objective).	[2012]	done	3.2.12.2	2011	3.2.11.6
1.A.4.	Currently, the greenhouse-gas inventory for sea transports, including transports between German seaports, is being thoroughly revised. The findings and results from that effort will enter into future reporting on category 1.A.4.c iii.	The findings and results from the relevant project on maritime transports, FKZ 3709 43 111 / 01, need to be integrated within the inventory.	[2012]	done	3.2.12.2	2012	3.2.11.6
1.B.2	A research project is currently underway with the aim of studying emissions from the gas network. The project's initial results indicate that the emissions figures reported to date have been much too high, since the emission factors used are based on a high assumed frequency of damage and since the materials used in pipelines have been considerably improved with regard to gas tightness.	Project results are to be integrated into the inventory.	[2015]	done		2013	3.3.2.2
1.B.2.a.v	A research project will be carried out to update data for cleaning of railway tank cars (UBA 2004b) and to obtain data for other cleaning areas, such as cleaning of inland-waterway tanker ships and road tankers.	The data on cleaning of railway tanker cars (UBA 2004b), and data for other areas of cleaning such as inland-waterway tanker ships and road trankers, need to be updated / determined via the research project. The inventory then has to be revised accordingly.	[2015]	done		2012	3.3.2.3.5.6
1.D.1.b.	A study is currently gathering AIS- based ship-movement data. The resulting bunkering-quantities data will then be used, in combination with also-updated specific emission factors, for description of the emissions to be assigned to Germany.	Results from the AIS project have to be integrated within the inventory.	[2012]	done	3.2.2.3.2	2011	Kap.3.2.2.3.6
1.D.1.b.	In the framework of a study, ship-movement data are currently being determined via the Automatic Identification System (AIS; a radio-based and satellite-based system for transmission of ship data such as size, load, speed, route, etc.). The resulting bunkering-quantities data will then be used, in combination with also-updated specific emission factors, for description of the emissions to be assigned to Germany.	Results from the AIS project have to be integrated within the inventory.	[2012]	done	3.2.2.3.2	2012	3.2.2.3.6
3.B.	The method used for calculation of GG emissions from slurry digestion was unable to take account of small amounts of slurry (cf. Chapter 6.1.3.6.5). The calculation method is to be revised to enable inclusion of such amounts of slurry.	Due to conceptional restrictions small amounts of slurry are not taken into emission calculation. To corecct this ommision the calculation method shall be adjusted. Results are to be integrated into the inventory.	[2015]	done	5.1.3.6.5	2013	6.3.2.6 + 6.3.4.6

CRF-New	Planned improvement	Data quality objective	Deadline	Status	Resolved in NIR-Chapter	Year of Reporting	Reference NIR-Chapter
2.D.3.(c)	The VDD plans to carry out additional considerations relative to export-import offsetting.	A new relevant expert (Fachverantwortlicher) will have to re-study the data relative to correction of foreign-trade statistics – possibly, via the National Co-ordinating Committee. (cf. also "additional need for action")	[2012]	overdue		2011	4.2.5.6
2.D.3.(b)	Relevant findings currently available from a research project are to be used for specific evaluation of emission factors.	The emission factors need to be evaluated on the basis of the existing project report.	[2012]	overdue		2011	4.2.6.6
1.A.3.a	No improvements are currently planned, apart from ongoing routine revisions of the TREMOD AV model.	Improvements due to the revision of the TREMOD-Aviation model are to be iplemented into the inventory and completely documented.	[2016]	to do		2015	3.2.10.1.6
1.A.3.b.	No improvements are currently planned, apart from ongoing routine revisions of the TREMOD AV model.	Improvements due to the revision of the TREMOD model are to be iplemented into the inventory and completely documented.	[2016]	to do		2015	3.2.10.2.6
1.A.3.d.	In the framework of updating of the BSH model (BSH = Federal Maritime and Hydrographic Agency), various types of maintenance work on the model are carried out. Such work cannot be specified at present, however.	Improvements due to the revision of the TREMOD- and the BSH-Modell are to be integrated into the inventory and be completely documented.	[2016]	to do		2015	3.2.10.4.6
4.B, 4.C	Organic soils: Greenhouse gas measurements for improvement and validation of the relevant emission factors: ongoing research project.	The national emission factors for organic soils need to be improved and validated with the help of greenhouse-gas measurements.	[2016]	done	6.1.2.2.2	2012	7.3.8
4.B, 4.C, 4.D	New emission factors, differentiated by soil type and soil use, for organic soils	Determination of differentiated EF for organic soils.	[2016]	done	6.1.2.2	2011	7.3.8, 7.4.8, 19.5.2.6
1.A.4.a.i.	With regard to reporting on stationary combustion systems, review is currently being carried out to determine whether the applicable percentage for wood use can be determined via other scientific studies.	After finalization of the feasibility assessment for estimating the share of wood use via different scientific studies, the results - if any - are to be integrated into the inventors and be completely documented.	[2016]	to do		2015	3.2.11.6
4.C.	Furthermore, the previously used provisional emission factor for tree/shrub biomass has been improved, via inclusion of results from ten tree/shrub plantations in addition to the results from previously studied plantations.	The preliminary emissionfactor shall be revised and the inventory be updated.	[2016]	done	6.6.2.2.2	2013	7.4.8
4.D.	In the wetlands category, an effort is being made to derive country-specific emission factors for emissions of the greenhouse gases CO_2, N_2O and CH_4 from peat extraction. To this end, measurements are being carried out, in the framework of the project "Organic Soils", that cover all phases of this form of land use (cf. Chapter 19.5.2.6). The results will be used for parametrisation and validation of mathematical models, and for determination of country-specific, regional default factors. As soon as they become available, the results of this project will enter into national reporting.	The results from the project have to be integrated within the inventory.	[2015]	done	6.7.2.5	2011	7.5.8
5.A.1.	In 2011/12, the residual-gas emissions from landfill storage of mechanically and biologically treated waste were quantified in an expert opinion (IFAS, 2012). The opinion confirms that emissions calculations to data have been correct in applying low emissions contributions from landfilling of MBT waste. In addition, with regard to the progression of methane formation, the opinion provides indications of higher fractions of waste components with shorter half-lives in decomposition. This issue is being reviewed at present. ~~In the NIR 2014,~~ The half-lives / reaction constants for MBT waste may be adjusted as a result.	The inventory shall be improved on the basis of the surveys results. The survey and its results shall be documented.	[2014]	done		2013	8.2.1.6
5.B.1.	As part of adjustments being made for harmonization with the 2006 Guidelines, plans for the next report call for introduction of new emission factors for recycling of biowaste. A research project for determining these factors will soon be completed.	As part of adjustments being made for harmonization with the 2006 Guidelines, plans for the next report call for introduction of new emission factors for recycling of kitchen waste. A research project for determining these factors will soon be completed.	[2015]	done	7.3.1.2	2014	8.5.1.6
1.D.1.a.	No improvements are currently planned, apart from ongoing routine revisions of the TREMOD AV model.	Improvements due to the revision of the TREMOD-Aviation model are to be iplemented into the inventory and completely documented.	[2016]	to do		2015	3.2.2.2.6
1.D.1.b.	In 2013 or later, use will begin of LNG bunkered in Germany. Such use will duly be taken into account in future reports.	LNG bunkered in germany shall be included into the inventory.	[2015]	overdue		2013	3.2.2.3.6

CRF-New	Planned improvement	Data quality objective	Deadline	Status	Resolved in NIR-Chapter	Year of Reporting	Reference NIR-Chapter
1.D.1.b.	No improvements are currently planned, apart from ongoing routine revisions of the calculation model used pursuant to (BSH, 2014).	Improvements due to the revision of the BSH model are to be iplemented into the inventory and completely documented.	[2016]	to do		2015	3.2.2.3.6
2.B.4.a.	Plans call for the production quantities of ε-caprolactam as of 2009 to be determined via other sources, and for the N_2O reductions of other producers to be determined.	Results of the survey related to verification of produced caprolactam and of N2O-mitigation efforts have to be implemented in the national inventory and reporting and be completely documented.	[2016]	to do		2015	4.3.4.6
2.C.6.	Specific data for determination of emission factors will be collected in the next rounds of reporting.	Revision of EF as well as complete documentation of results..	[2016]	to do		2015	4.4.6.6
2.D.3.(b)	Relevant findings currently available from a research project are to be used for specific evaluation of emission factors.	The emission factors need to be evaluated on the basis of the existing project report.	[2012]	overdue		2012	4.2.6.6
2.D.3.(c)	The VDD plans to carry out additional considerations relative to export-import offsetting.	A new relevant expert (Fachverantwortlicher) will have to re-study the data relative to correction of foreign-trade statistics – possibly, via the National Co-ordinating Committee.	[2012]	overdue		2012	4.2.5.6
5.D.2.	Plans call for review of the possibility of determining the COD values for the sector-specific wastewater streams.	Check wether CSB-values for branchspecific wastewater flows can be determined. Where appropriate the inventory shall be revised.	[2014]	done	7.5.2	2013	8.3.1.2.6
3.A.	In data management and emissions calculations for this area, a transition is being made from spreadsheet files to a relational database and procedural programmes. That step, for which work began in summer 2010, is oriented primarily to QC/QA purposes. Its benefits, for example, will include facilitation of automatic plausibility checks.	The relational database needs to be completed.	[2017]	to do		2011	6.2.6
3.A.	In data management and emissions calculations for this area, a transition is being made from spreadsheet files to a relational database and procedural programmes. That step, for which work began in 2010, is oriented primarily to QC/QA purposes. Its benefits, for example, will include facilitation of automatic plausibility checks.	The relational database needs to be completed.	[2017]	to do		2012	6.2.6
3.B.	In data management and emissions calculations for this area, a transition is being made from spreadsheet files to a relational database and procedural programmes. That step, for which work began in summer 2010, is oriented primarily to QC/QA purposes. Its benefits, for example, will include facilitation of automatic plausibility checks.	The relational database needs to be completed.	[2017]	to do		2011	6.3.2.6
3.B.	In data management and emissions calculations for this area, a transition is being made from spreadsheet files to a relational database and procedural programmes. That step, for which work began in 2010, is oriented primarily to QC/QA purposes. Its benefits, for example, will include facilitation of automatic plausibility checks.	The relational database needs to be completed.	[2017]	to do		2012	6.3.2.6
3.D	In data management and emissions calculations for this area, a transition is being made from spreadsheet files to a relational database and procedural programmes. That step, for which work began in summer 2010, is oriented primarily to QC/QA purposes. Its benefits, for example, will include facilitation of automatic plausibility checks.	The relational database needs to be completed.	[2017]	to do		2011	6.5.6
3.D	In data management and emissions calculations for this area, a transition is being made from spreadsheet files to a relational database and procedural programmes. That step, for which work began in summer 2010, is oriented primarily to QC/QA purposes. Its benefits, for example, will include facilitation of automatic plausibility checks.	The relational database needs to be completed.	[2017]	to do		2012	6.5.6
4.	The results of the Agricultural Soil Inventory are being used for step-by-step validation of the current emission factors.	The currently used EF are to be verified with the results of the Agricultural Soil Inventory	[2019]	to do		2014	19.5.2.3
4. LULUCF (Total area)	Development of new, country-specific emission factors for mineral soils, via a major inventory (Agricultural Soil Inventory).	Integration of new EF for mineral soils into the inventory and complete documentation of background data, results and assumptions.	[2021]	to do		2015	6.1.5

CRF-New	Planned improvement	Data quality objective	Deadline	Status	Resolved in NIR-Chapter	Year of Reporting	Reference NIR-Chapter
4. LULUCF (Total area)	Complete integration of the organic soils map within the sampling procedure used in the grid-point approach for determination of the land-use matrix.	Integration of resulting changes into the inventory and complete documentation of background data, results and assumptions.	[2016]	to do		2015	6.1.5
4. LULUCF (Total area)	Derivation of country-specific emission factors, and development of models for determination of the impacts of cultivation on cropland and grassland areas, using data from the Agricultural Soil Inventory, data from long-term soil monitoring and mathematical models.	Integration of new EF for mineral soils into the inventory and complete documentation of background data, results and assumptions.	[2019]	to do		2015	6.1.5
4.A.	*Litter and mineral soils* Evaluation of the data relative to changes in organic carbon in the upper 30 cm of mineral soil shows that sandy soils in particular, soils whose distribution is concentrated in northern Germany, have accumulated carbon since the BZE I survey. A study is already underway, with regard to the BZE, to determine the reasons for the carbon increase. A comparison with a regional soil inventory carried out on long-term study areas (KONOPATZKY 2009) indicates that changes have taken place primarily in recent years. On the other hand, a study carried out in the framework of the BZE has concluded that significant changes of carbon stocks in mineral soil take at least 10 years to become apparent in surveys (MELLERT et al. 2007). It is thus necessary to determine the relevant rate of change via a follow-on inventory. The time for that inventory will be determined after evaluation of the BZE II survey has been completed.	Once the Forest Soil Inventory II (BZE II) has been evaluated, a follow-on inventory needs to be initiated to determine changes in organic carbon in the top 30cm of mineral soils (cf. the relevant individual objective).	[2017]	to do		2011	7.2.8.2
4.A.	Evaluation of the data relative to changes in organic carbon in the upper 30 cm of mineral soil shows that sandy soils in particular, soils whose distribution is concentrated in northern Germany, have accumulated carbon since the BZE I survey. A study is already underway, with regard to the BZE, to determine the reasons for the carbon increase. A comparison with a regional soil inventory carried out on long-term study areas (KONOPATZKY 2009) indicates that the changes have taken place primarily in recent years. On the other hand, a study carried out in the framework of the BZE has concluded that significant changes of carbon stocks in mineral soil take at least 10 years to become apparent in surveys (MELLERT et al. 2007). It is thus necessary to determine the relevant rate of change via a follow-on inventory. The time at which that inventory is to be carried out will not be decided until after the BZE II inventory has been evaluated.	Once the Forest Soil Inventory II (BZE II) has been evaluated, a follow-on inventory needs to be initiated to determine changes in organic carbon in the top 30cm of mineral soils.	[2017]	to do		2012	7.2.8.2
4.B, 4.C	Improvement of the area data for organic soils under cultivation: ongoing research project.	The area data for organic soils on cropland need to be improved.	[2016]	to do		2012	7.3.8
4.B, 4.C	Mineral soils: Agricultural soil inventory: generation of national measurements of C stocks, for cropland and grassland.	On the basis of the Agricultural Soil Inventory, data on C stocks in mineral soils need to be derived for cropland and grassland, and the inventory has to be improved accordingly.	[2020]	to do		2012	7.3.8
5.A.1.	In an international comparison, collection rates of landfill gas, at about 20 %, seem very low. They also seem low in that nearly all German landfills have gas-collection facilities and that the technical characteristics of German landfills would seem to provide a comparatively good basis for high collection rates. This apparent contradiction will need to be cleared up for future reports.	The causes for the high differences between statistical data and estimated amount of landfill gas shall be determined.	[2018]	to do		2013	8.2.1.6
5.E.1	The emission factors used to date for methane and nitrous oxide are the emission limit values specified in the 30th BImSchV. The actual emissions of the facilities involved are considerably lower than those emission limit values. For future reporting, therefore, it will be necessary to evaluate the actual facility emissions and to review the pertinent emission factors.	Until now emission thresholds based on the 30. BImSchV are used as emission factors for CH4 and N2O. Real plant emissions are assumed to be far below these thresholds. Actual plant emissions shall be evaluated, the emission factors be checked and the inventory be updated.	[2015]	overdue		2013	8.5.2.6

10.2.2 KP & LULUCF

The LULUCF-sector improvements described for the Convention inventory, in Chapter 6.1.3, are also to be applied to the KP-LULUCF inventory.

10.2.3 Implementing Regulation Article 9: Reporting on implementation of recommendations and adjustments

Table 342: Implementing Regulation Article 9: Reporting on implementation of recommendations and adjustments, Article 9.1

Member State:	**Germany**			
Reporting year:	**2013 -- Implementation of ARR 2014 was not possible due to considerable delay of the finalized version until 28.04.2015!**			
CRF category / issue	**Review recommendation**	**Review report / paragraph**	**MS response / status of implementation**	**Chapter/section in the NIR**
0.	Germany described in the NIR that it determines uncertainties with a tier 2 analysis every three years. The latest tier 2 uncertainty analysis was carried out in 2010, and it should have been carried out again in 2013. However, according to the NIR, Germany extensively revised the calculation algorithms, and integrated uncertainty calculation within CSE in 2012. Although initial results have already been obtained with the new approach, neither they nor the basic change in methods have yet been verified. The necessary review for verification will be carried out in 2013 and the results of the tier 2 uncertainty analysis will be reported as part of the 2014 annual submission. The ERT welcomes the plan	§ 13, Table 4	Germany is continuing to work on that issue.	- -
0.	The ERT noted that the reasons for the higher uncertainty estimates in the current annual submission were not clearly explained in the NIR. To increase transparency, the ERT encourages Germany to explain the differences in the uncertainty estimates for the consecutive annual submissions in the NIR	§ 13, Table 4	Germany is continuing to work on that issue.	- -
0.	The ERT noted that in general, quantitative uncertainties for AD and EFs at an aggregated level are available in the NIR (table 387), but quantitative uncertainty estimates are not provided in the category-specific sections of the NIR. In response to questions raised by the ERT during the review, Germany provided the ERT with the spreadsheets which included category-specific uncertainties for AD, EFs and combined uncertainty of emissions according to the fuel type. The ERT recommends that the Party include brief information on quantitative uncertainties in the category-specific sections in the NIR.	§ 25	Germany is continuing to work on that issue.	- -
0.	The ERT noted inconsistencies between the information included in the CRF tables and in the tables of the NIR, which specify the method and EFs used in all sectors except solvent and other product use. Germany explained that it has implemented a tier 1 QC procedure for checking the consistency of information between the text in the NIR and CRF table summary 3. The ERT recommends that Germany enhance the effective implementation of the tier 1 QC check for transcription errors.	§ 8, Table 3	Resolved with an additional NIR-CRF-check after completion of the NIR. With emission reporting 2015 new check routine will be added to the checklist of the NIR-Coordinator.	- -
0.	The ERT recommends that Germany improve transparency of the inventory by ensuring that the notation keys are used correctly and that the information is consistent between the NIR and the CRF tables for all sectors.	§ 8, Table 3	Resolved with an additional NIR-CRF-check after completion of the NIR. With emission reporting 2015 new check routine will be added to the checklist of the NIR-Coordinator.	- -
1.	To further increase the transparency of the inventory, the ERT also reiterates the encouragement in the previous review report to include in the NIR details of primary fuel types for the entire time series.	§ 22	Germany is continuing to work on that issue.	- -
1.	The ERT noted that Germany has used EU ETS data for the verification of some emission estimates. According to the NIR, a formalized procedure has been agreed for the relevant annual data exchange. The ERT reiterates the encouragements made in the previous review reports that Germany continue to use the EU ETS data to verify EFs and/or emission estimates and to analyse any significant differences between the two data sources and report on this in the NIR.	§ 23	Chapter 18.7.4 comparison of ETS emission factors and NCVs with inventory data	NIR 2014 Chapter 18.7.4
1.	In 2011, total CO_2 emissions estimated using the reference approach were 0.8 per cent lower than those estimated using the sectoral approach. However, at the primary fuel level the comparison results in larger differences, as presented in CRF table 1.A(c), especially for liquid fuels (10.5 per cent) and solid fuels (–7.4 per cent). Similar differences in emissions exist for all years since 1990. There are no explanations for the differences at the fuel level provided in the NIR. Therefore, the ERT reiterates the recommendation made in the previous review report that Germany include a detailed analysis of emission differences at the primary solid, liquid and gaseous fuel levels in the NIR.	§ 27	chapter 20 explanation of differences between reference and sectoral approach at fuel level	NIR 2014 chapter 20

Member State: Germany

Reporting year: 2013 -- Implementation of ARR 2014 was not possible due to considerable delay of the finalized version until 28.04.2015!

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
1.	The ERT noted that Germany continues to use carbon storage fractions for natural gas (0.90) and liquefied petroleum gas (0.55) that differ significantly from the defaults contained in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (hereinafter referred to as the Revised 1996 IPCC Guidelines) (0.33 and 0.80, respectively) and the NIR did not provide proper justifications for these differences. In response to a question raised by the ERT during the review, Germany explained that the values have not yet been changed to IPCC defaults owing to a mistake and also explained that for the 2014 annual submission, the Party will revise the carbon storage fractions. The ERT welcomes the planned improvement and reiterates the recommendation made in the previous review report that the Party provide justifications for the carbon storage fractions and for any recalculations performed.	§ 30	The named fractions of carbon stored have been reset to IPCC defaults. - see NIR 2014, chapter 20, Annex 4	NIR 2014 see NIR 2014, chapter 20, Annex 4
1.	As noted in the previous review reports, additional information for feedstocks and non-energy use of fuels in CRF table 1.A(d) has not been reported for any of the years. The ERT considers that inclusion of this information would increase the transparency of the reporting and facilitate understanding of the overall energy balance. The ERT reiterates the recommendation made in previous review reports that Germany include this additional information in CRF table 1.A(d).	§ 31	Additional information has been included in the respective table of CRF table 1.A(d).	NIR 2014 CRF table 1.A(d)
1.A	The ERT noted that in 2011, the total apparent consumption reported in the CRF tables is 3 per cent lower than that reported to IEA. The ERT reiterates the recommendation made in the previous review report that Germany compare the inventory data with the corresponding IEA data at the primary fuel type level and explain the differences in the NIR.	§ 28	Chapter 3.2.1.2.1 provides an explanation for the reasons.	NIR 2014 Chapter 3.2.1.2.1
1.A.1.a	Recalculations are listed in the NIR by category but are in some cases not transparently explained and quantified. For example, in the NIR (page 159) it is stated that a recalculation for public electricity and heat production was required “for the period as of 2004 as a result of revision of the applicable waste model”. The ERT further noted that this issue was not mentioned in CRF table 8(b). In response to a question raised by the ERT during the review, Germany explained that previously a comparison between the energy and the waste statistics was possible only at an aggregated level. For the 2013 annual submission, very detailed waste incineration data according to the classification of the European Waste Catalogue became available. Additional data on the amount of waste combusted in co-incineration plants (hard coal and lignite fired power plants) were also available from the coal association and the European Union emissions trading scheme (EU ETS). The ERT commends the Party for the improvements but recommends that the Party include sufficient explanatory information justifying recalculations in the NIR to improve transparency.	§ 21	Issue has been resolved.	- -
1.A.1.b	The ERT noted that the overall trend of the CO2 implied emission factor (IEF) in the solid fuel category for petroleum refining has decreased between 1990 (93.09 t/TJ) and 2011 (40.00 t/TJ) by 57.0 per cent. The CO2 IEF has been constant since 1997. In 2011, the CO2 IEF was the lowest among the reporting Parties (40.00–262.48 t/TJ) and below the range of the IPCC default values (94.60–106.70 t/TJ). In response to a question raised by the ERT during the previous stages of the review, Germany stated that this decrease can be explained by the use of coke oven gas in 2011 instead of lignite, which was used in 1990. The ERT reiterates the recommendation made in the previous review report that Germany provide a brief explanation of this issue to improve transparency.	§ 32	Chapter 3.2.7.1 improved trend description	NIR 2014 Chapter 3.2.7.1
1.A.2	The ERT noted that Germany continues to report emissions under manufacturing industries and construction in an aggregated manner: 69.7 per cent of the total emissions from manufacturing industries and construction in 2011 are reported in the subcategory other. In response to a question raised by the ERT during the review, Germany explained that QA/QC is easier at an aggregated level and a further disaggregation would increase the complexity of the inventory but not improve the quality. However, the Party mentioned that it is continuing to work on that issue. The ERT reiterates the recommendation made in the previous review report that Germany continue to assess the possibility of preparing emissions data at the level of disaggregation in the CRF tables, and report on progress in its next annual submission.	§ 24	The possibility of preparing emissions data for manufacturing industries and construction at the level of disaggregation in the CRF tables has been assessed. See Chapter 3.2.9.11.1	NIR 2014 See Chapter 3.2.9.11.1

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CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
1.A.2.a	The ERT has identified several large inter-annual changes in the CH4 IEF for the subcategory iron and steel, including from 0.72 kg/TJ in 2002 to 5.44 kg/TJ in 2003 (increase of 652.7 per cent) and from 2.78 kg/TJ in 2008 to 0.86 kg/TJ in 2009 (decrease of 69.2 per cent). In response to a question raised by the ERT during the review, Germany explained that the fuel category gaseous fuels includes both natural gas and pit gas. Natural gas is mostly used in boilers and power plants, mixed with blast furnace gas, oxygen furnace gas and coke oven gas. Pit gas is burned in engines with considerably higher CH4 emissions. The relationship between the two fuel types changes every year, mainly due to the availability of pit gas. The ERT recommends that Germany provide a brief explanation of this issue in its NIR to increase transparency.	§ 36	Subcategory is irrelevant compared to the total of category emissions. An explanation of the inter-annual changes of the IEF can be given on request, but yearly revision of the trend is exceeding the entitys resources.	- -
1.A.3.b	The N2O IEF for diesel oil in road transportation has an increasing trend (0.54 to 2.79 kg/TJ between 1990 and 2011), and there are several large inter-annual changes in the time series, such as a 22.0 per cent increase from 2007 (1.64 kg/TJ) to 2008 (2.00 kg/TJ); a 14.2 per cent increase from 2008 to 2009 (2.28 kg/TJ); a 12.0 per cent increase from 2009 to 2010 (2.56 kg/TJ) and a 9.3 per cent increase from 2010 to 2011 (2.79 kg/TJ). In response to a question raised by the ERT during the review, Germany explained that the development of the N2O IEF strongly reflects the increasing share of diesel vehicles and the ongoing implementation of mitigation technologies (European emission standards) for these vehicles, especially in order to reduce nitrogen oxides emissions, resulting in higher N2O emissions. The ERT recommends that Germany provide a brief explanation of this issue in its NIR to increase transparency.	§ 37	A brief explanation for the development of the N2O IEF for diesel oil in road transportation provided in NIR. - see NIR 2014, chapter 3.2.10.2 Transport – Road transport (1.A.3.b)	NIR 2014 see NIR 2014, chapter 3.2.10.2 Transport – Road transport (1.A.3.b)
1.A.3.d.i	The ERT noted that due to lack of usable AD, Germany cannot distinguish the small amount of bunker fuel that is used for international transport on inland waterways (such as on the Rhine river) from that used for domestic navigation, as indicated in the previous review reports. The ERT also noted that the approach of Germany leads to a potential slight overestimation of emissions from navigation. Taking into consideration the small contribution of the category to the national totals, the ERT encourages Germany to make efforts to separate the emissions from international transport associated with inland navigation from the emissions from domestic navigation, taking into account the availability of resources.	§ 38	Issue has been resolved.	NIR 2015 3.2.10.4
1.A.4	The CH4 IEF for solid fuels in the subcategory commercial/institutional has a decreasing trend: from 239.90 kg/TJ in 1990 to 108.91 kg/TJ in 2011 (–54.6 per cent). In 2011 the CH4 IEF was considerably higher than the IPCC default value (10.0 kg/TJ), and third highest among the reporting Parties (range from 0.071 to 427.34 kg/TJ). In response to a question raised by the ERT during the review, Germany explained that a country- specific EF for CH4 has been derived from measurement values and it can be explained by a relatively large share of small appliances with high CH4 emissions. The ERT recommends that Germany provide a brief explanation of this issue in its NIR to improve transparency.	§ 35	Subcategory is irrelevant compared to the total of category emissions. An explanation of the inter-annual changes of the IEF can be given on request, but yearly revision of the trend is exceeding the entitys resources.	- -
1.B.2.b	The CH4 emissions from natural gas production/processing increased by 17.8 per cent from 2007 to 2008 (from 2.93 Gg to 3.46 Gg) and by 11.2 per cent from 2008 to 2009 (3.84 Gg). From 2009 to 2010 (2.21 Gg) the emissions decreased by 42.4 per cent. In response to a question raised in the previous stages of the review, Germany explained that the amount of gas produced and thus also emissions have generally a decreasing trend. According to the German association of the oil and gas industry (Wirtschaftsverband Erdöl- und Erdgasgewinnung e.V.) the production plants were optimized in the years 2008–2009, which led to higher emissions in those years. Germany further stated that the variance between the yearly emission amounts is within the specified range of the uncertainty (NIR chapter 3.3.2.4.2.3). The ERT recommends that Germany provide an explanation of this issue in the NIR and ensure that the reasons for such fluctuations are appropriately reported in the NIR.	§ 33	Germany already stated that the variance between the yearly emission amounts is within the specified range of the uncertainty .	NIR 2015 3.3.2.4.2.3

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1.B.2.b	The CH_4 emissions from natural gas transmission increased by 19.6 per cent from 2008 (14.01 Gg) to 2009 (16.75 Gg) and decreased by 4.8 per cent from 2009 to 2010 (15.95 Gg). In response to a question raised by the ERT during the previous stages of the review, Germany explained that the volume of gas stored in reservoirs in 2009 was higher than usual, and also the reported length of steel pipeline was higher than in the years before or after 2009. Germany explained that neither the association of the oil and gas industry nor UBA can provide a reasonable explanation for these anomalies. In an attempt to avoid underestimation, Germany estimated emissions using the pipeline length reported for 2009 instead of interpolation. The Party also explained that the uncertainty of this subcategory is 20 per cent. The ERT encourages Germany to investigate this variance and report on it in the NIR.	§ 34	Germany already stated that the variance between the yearly emission amounts is within the specified range of the uncertainty .	NIR 2015 3.3.2.4.2.3
2.	The NIR and the CRF tables are generally transparent. The notation key “IE” (included elsewhere) is used in the industrial processes sector to report CO_2 emissions from limestone and dolomite use and from ceramic production (a country-specific subcategory under other (mineral products)), CO_2 and CH_4 from pig iron, coke and sinter, and N_2O from medical use (country-specific subcategory under other (chemical industry)). In the solvent and other product use sector, emissions from aerosol cans are reported as “IE”. The Party has explained under which categories the emissions are reported, but the ERT encourages the Party to decrease the number of instances where the notation key “IE” is used.	§ 40	Issue has been checked, but in some cases "IE" remains as the appropriate notation key.	- -
2.	Not all recalculations mentioned in CRF table 8(b) are explained in the NIR (such as that for SF_6 used as trace gas). The ERT reiterates the recommendation made in the previous review report that the Party improve the consistency of the information in CRF table 8(b) with that presented in the NIR.	§ 41	Issue cannot be resolved entirely. This is due to the fact, that there are a lot of recalculations that are of such a minor effects, that they cannot be reasonably and completely addressed in the NIR. That’s why they are addressed on aggregated level only, whereas CRF table 8(b) is complete. That’s the only reason for the differences.	- -
2.A.1	Germany has calculated CO_2 emissions from cement production on the basis of clinker production, with a country-specific EF of 0.53 t CO_2/t clinker, which is higher than the IPCC default value (0.51 t CO_2/t clinker). Although the overall EF is higher than the IPCC default value, the previous ERT noted that Germany did not apply a correction for cement kiln dust. Germany explained in the NIR that there is no need to take account of significant losses via the exhaust-gas pathway because dust separated from the exhaust gases is returned to the burning process in the German cement industry. This means that the cement kiln dust correction factor is 1.00. Based on the explanation given by Germany in the NIR, the ERT considers that the method used corresponds to the IPCC tier 2 method, which is appropriate for this key category. In the previous review report, the Party was encouraged to verify the emission data with data from the EU ETS. In response to questions raised by the ERT during the current review, Germany provided the comparison of CO_2 emission data presented in the NIR and those in the EU ETS reports between 2005 and 2011. The ERT noted that the CO_2 emissions from cement production reported in the NIR are higher than those reported in the EU ETS reports. The range of difference is from 1.2 per cent in 2005 to 7.3 per cent in 2011. The ERT commends Germany for providing this information and encourages the Party to include CO_2 emissions at the national level from the EU ETS report in the NIR for verification purposes, and to explain the significant difference.	§ 42	to do for submission 2016, now only emission factor is checked	NIR 2015 4.2.1

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CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
2.A.2	According to the NIR, the German Lime Association collects lime production data for the entire time series and the NIR states that this approach ensures that all German lime production is taken into account in the inventory. Germany recalculated the emissions from lime production in the 2013 annual submission for the entire time series taking into account the default factor of 5.0 per cent impurities in raw materials, which was not included in the emission estimates in the previous annual submission. The recalculation resulted in a 5.0 per cent decrease in the CO2 emissions from the category. The ERT concluded that the method used is in line with the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (hereinafter referred to as the IPCC good practice guidance). In response to questions raised by the ERT during the review, Germany provided a comparison table of CO2 emissions from lime production between the NIR and the EU ETS for 2005–2011. The ERT noted that the CO2 emissions reported in the NIR are lower than those from the EU ETS. The range of differences is from 11.9 per cent in 2005 to 8.9 per cent in 2011. In response to a further question raised by the ERT, the Party explained that at the moment, the correction factor for impurities used for the national GHG inventory calculations cannot be changed from the default value to a value corresponding to EU ETS results due to lack of sufficient knowledge on the issue. The ERT reiterates the recommendation made in the previous review report that Germany analyse the differences between the CO2 emissions reported in the NIR and those from the EU ETS and report on this in the NIR. The ERT further recommends that the Party provide EU ETS methodology and the EFs used to calculate CO2 emissions from lime production in the next annual submission to improve transparency.	§ 43	It's checked, but it is not possible to provide EU ETS methodology over three trading periods.	NIR 2015 4.2.2
2.A.3	Germany continues to report CO2 emissions from limestone and dolomite use as “IE” and the emissions are included in the categories where limestone and dolomite are consumed (e.g. under iron and steel production or public electricity and heat production (flue gas desulphurization)). However, according to the Revised 1996 IPCC Guidelines, emissions from limestone and dolomite use, except for cement production, lime production and agriculture, are to be reported in the category limestone and dolomite use. The ERT recommends that the Party reallocate CO2 emissions from limestone and dolomite use following the Revised 1996 IPCC Guidelines.	§ 50	Obsolete, due to entry ino force of the 2006 GL.	- -
2.B.1	Germany estimated the emissions based on the carbon content of the raw materials (natural gas and heavy fuel oil). In line with the Revised 1996 IPCC Guidelines, the Party included in the emissions the recovered CO2 that is used in, for example, the production of urea. The amount of recovered CO2 is reported as “NO” (not occurring) in the CRF tables. The ERT reiterates the recommendation made in the previous review report that the Party change the notation key to “IE”. The ERT also reiterates the recommendation made in the previous review report that the Party include in the NIR information on how the carbon content of heavy fuel oil used in ammonia production is determined, to improve transparency.	§ 45	See CRF table 2014 2(I).A-Gs1 Germany changed the notation key from NO to IE and added an explanation that the recovered amounts according the guidelines 19906 are reported at the emissions in CRF 2.B.1 and in NIR chapter 4.3.1.2 Methods (2.B.1) Germany delivers the explanation for each plant how the carbon content factor is developed.	NIR 2014 See CRF table 2014 2(I).A-Gs1
2.B.3	The emissions from adipic acid production included in the inventory for 1990 until the mid-1990s are based on IPCC default EFs and the amount of adipic acid produced, obtained from the producers. Thereafter, the emission estimates reported are based upon emission data reported by the plants. Production data and IEFs are reported as confidential. In response to a question raised by the ERT during the previous review, Germany provided the confidential production data and the time series for the calculated IEFs based on reported total emissions and production for the category. The three facilities producing adipic acid have installed abatement technologies. The ERT reiterates the recommendation made in the previous review report that Germany improve the description of the methodological issues for the calculation of the N2O emissions (e.g. precisely for which years the IPCC default EF is used, and the methods used to calculate N2O emissions at each plant) in its NIR, to improve transparency.	§ 46	In NIR chapter 4.3.3.2 methods (2.B.3) Germany added the information that the emissions are measured continuosly in all plants and that the default EF is used for one plant until 1993 and the other plant until 1997.	NIR 2014 chapter 4.3.3.2

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2.B.5.(f)	In 2011, CO2 emissions from other (chemical industry) contributed 13.3 per cent of the total GHG emissions from the industrial processes sector. The main contributors to CO2 emissions were: burn-off of coke as a catalyst at oil refineries; production of carbon black and methanol; and transformation processes. The methodology used to estimate emissions from coke burn-off in catalyst regeneration is not clearly described in the NIR. The ERT reiterates the recommendation made in the previous review report that Germany include a more detailed description of methodological issues in the NIR, including explanations of whether the emissions are the result of fuel use for the production of energy, to improve transparency.	§ 47	In NIR chapter 4.3.5.2 Methods 2.B.5 Germany added informations about the method how the emissions from catalytic reduction were estimated.	NIR 2014 NIR chapter 4.3.5.2
2.E	Germany reported in the NIR that up to mid-2010 there were two HCFC-22 production plants. Since production was terminated in 2010, the emissions did not occur in 2011. The ERT noted that in the CRF tables, Germany reported AD as “NE” (not estimated) and emissions as “C” (confidential). In response to a question raised by the ERT during the review, the Party explained that the correct notation key is “NO”. The ERT recommends that the Party correct the use of notation keys.	§ 48	In the CRF tables for 2011 and 2012 the notation key was changed from NE for AD and C for emissions to NO for both.	- -
2.F.1	In the 2013 annual submission, Germany recalculated the emissions from this category due to the introduction of a new model and data for calculating HFC emissions from commercial refrigeration, industrial refrigeration, stationary air-conditioning systems and mobile air-conditioning systems. The ERT noted that the specific refrigerant quantity (coefficient) for commercial refrigeration was changed from the unit of kg refrigerant per installed kW to the unit of kg refrigerant per m2 of sales floor area (for medium-sized supermarkets) and to the unit of kg refrigerant per store (for discount stores). During the review the ERT asked the Party to explain the rationale for this change in specific refrigerant quantity and provide technical information on how these new coefficients were determined. In response to the question, the Party explained that the approach of estimating the refrigerant quantity in supermarkets based on sales floor area is more realistic because it accounts for the growing refrigeration area and explained that this approach is also applied by some other EU countries and in the EU fluorinated gas model AnaFgas. The Party further explained that in the case of discount stores, the coefficient is expressed in units of kg per discount store, instead of per sales floor area. This is because the discount stores are homogeneously the same size (~ 800 m2), resulting in the coefficient of 80 kg refrigerant per store. The ERT concluded that the approach taken by the Party is in line with good practice and improves the accuracy of the inventory. The ERT commends the Party for its detailed explanation and recommends that the Party include this information in the NIR to improve the transparency.	§ 49	In NIR chapter 4.7.1.2.2 the new model for the emissions calculation from commercial refrigeration is detailed described.	NIR 2014 chapter 4.7.1.2.2
4.	The ERT considered that the information provided on the parameters, EFs and assumptions for subcategories was not sufficiently detailed. In response to the questions raised by the ERT during the review on providing disaggregated parameters, EFs and calculation models, as well as the process of data aggregation and related background documents, Germany provided a report, “Calculations of gaseous and particulate emissions from German agriculture 1990 – 2011. Report on methods and data (RMD) Submission 2013”. The report described in detail the inventory calculation for the agriculture sector, including the model descriptions and rationale for the selection of parameters for each subcategory. The ERT noted that in 2012, Germany included as part of its annual submission a separate report and Excel files describing the inventory calculations for the agriculture sector. The ERT recommends that the Party follow a similar approach in the next annual submission, or provide the parameters and EFs by subcategory, as well as information on the process to aggregate data, in its NIR to improve transparency.	§ 52	The additional report and the Excel tables should always be part of the annual reporting and the NIR.	Rösemann et al. 2015
4.	The NIR stated that the Federal Statistical Office carries out surveys on cattle and swine twice a year (3 May and 3 November) and that the May data were used in the inventory. The data for sheep were collected in May up to 2010, but as of 2011, November reference data have been applied. However, there is no explanation or justification in the NIR regarding the change from May to November data. In response to a question raised by the ERT during the review, the Party explained that November reference data were used to be consistent with the EU statistics on German animal populations (Eurostat). Based on EU regulation 1165/2008, Article 4, the reference date was fixed to 3 November and, therefore, the November data correspond to the officially accepted annual animal number statistics. The ERT recommends that the Party ensure time-series consistency and report on this in a transparent manner in the NIR.	§ 53	More explaination is given in chapter 6.1.3.2.1 paragraph 2, p. 419.	NIR 2014 6.1.3.2.1 paragraph 2, p. 419.
4.A.(b)	Germany recalculated the gross energy intake values because of updated animal performance data, allocation of cows for fattening and slaughter to the suckler cows category instead of the heifers category, and due to a new national calculation method applied in the dairy cow model. The ERT noted that the table on gross energy intake was not updated in the NIR. In response to a request by the ERT during the review to provide detailed information on the parameters used in the calculations, Germany provided an updated table on gross energy intake. The ERT welcomes the improvements in the estimation of the emissions from enteric fermentation and recommends that the Party include the updated table on gross energy intake in the NIR.	§ 54	Table 164 includes the updated gross energy intake.	NIR 2014 Table 164

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4.B.(b)	In response to the recommendation made in the previous review report to provide detailed information on the amount of treated manure used for biogas production, Germany included anaerobic digestion of cattle and swine manure in the calculation model GAS-EM. In the NIR, a table of the percentage of slurry digested in biogas plants is provided. The ERT welcomes this improvement in transparency. However, there was no information in the NIR on how the data on the amount of slurry digested in biogas plants were collected. The ERT also noted that the estimated leakage rate of the digesters (1 per cent) is low. In response to a question raised by the ERT during the review, Germany provided a background document regarding data used to estimate emissions from biogas plants (KTBL, 2012a), explained the data sources sed to estimate the percentage of slurry digested in biogas plants, and clarified that the choice of a 1 per cent leakage rate is based on measurement results described in literature. The ERT recommends that Germany provide in the NIR a description of the data from which the percentage of slurry manure digested in biogas plants is derived, as well as a description of how the leakage rate is determined.	§ 55	More information is given under chapter 6.1.3.6.5, p. 438.	NIR 2014 6.1.3.6.5, p. 438.
4.B.(b)	In the previous review report, it was recommended that the Party either provide well-documented information on the herd size and housing systems of cattle and swine and detailed descriptions of manure management systems to justify the low EF value (0.005 kg N2O–N/kg N) for solid manure; or recalculate the emissions by using the default N2O EF from the Revised 1996 IPCC Guidelines. In response to that recommendation, a new national EF of 0.013 kg N2O–N/kg nitrogen (N) for solid manure was applied in the 2013 annual submission. The NIR provided information in an annex on the distribution of housing systems, storage systems and application techniques, as well as on the N excretion rates, which were updated for all animal types in the 2013 annual submission based on improved animal performance. However, the ERT considered that the information in the NIR was not sufficiently transparent to justify the updated EF. In response to a question raised by the ERT during the review, the Party provided a background report, “N2O emissions from solid manure storage. Calculation of a national emission factor”, to justify the new EF. In order to improve transparency, the ERT recommends that Germany summarize in the NIR the information provided in the above-mentioned report.	§ 56	The method is described in detail in reference "VANDRÉ et al. (2013): Vandré R, Wulf S, Häußermann U, Horlacher D: N2O emissions from solid manure storage – Calculation of a national emission factor. Landtechnik 68(1), 38 – 42."	- -
4.D	The ERT noted that Germany has used the amount of mineral fertilizer sold instead of the applied amount as AD to estimate N2O emissions from N fertilization. In response to a question raised by the ERT during the review, Germany explained that no data are available on the application of mineral fertilizer in Germany. However, data are available on the amount of fertilizer sold (annually on federal-state level from July of year n to June of year n+1). For the emission calculations it is assumed that the total amount of fertilizer sold in that period is applied in the year n+1 as there is no information on storage of mineral fertilizers. This assumption is in line with German farming practice, where most of the mineral fertilizer is applied in spring and early summer. The ERT considers that the approach of Germany is in line with good practice. The ERT recommends that Germany improve transparency by including the explanation on fertilizer data used in the NIR.	§ 57	More information is given under chapter 6.1.4.1.1, paragraph 2, p. 441,.	NIR 2014 6.1.4.1.1, paragraph 2, p. 441,
5.	The ERT acknowledges the improvements in the NIR, in particular the inclusion of information on annual areas subject to land-use changes among different categories for the periods 1990–2000, 2000–2005, 2005–2008 and 2008–2011. The ERT considers that inclusion of this information in the NIR improves the transparency regarding the reallocation of areas among different land-use change categories following the adoption of the new land-use change matrix based on a 20-year transition period. However, the ERT recommends that the Party include information in the NIR on how these changes in areas affect the IEFs for different land-use categories.	§ 59	In the chapter 7.1.2 more description is given.	NIR 2014 chapter 7.1.2
5.	As noted in the previous review report, the notation key “NO” is used for reporting many carbon pools and categories. For example, in the 2013 annual submission, “NO” is reported for dead organic matter for: wetlands; settlements remaining settlements; and cropland, grassland, wetlands and other land converted to settlements. The ERT noted that the IPCC good practice guidance for LULUCF does not include methods for these pools. In response to a question raised by the ERT during the previous review, the Party explained that the notation key “NE” has not been used because dead organic matter only occurs on forest land and not in the other land-use categories. The Party further explained that the biomass estimates for woody grassland and wood in wetlands and settlements include the whole plant, including leaves and roots, so that an extra dead organic matter pool could lead to double counting. The previous ERT noted that the estimation methodology provided in the IPCC good practice guidance for LULUCF involves estimating the changes in different carbon pools as a result of land-use management and conversion and not the absolute level of carbon stocks. The previous ERT further noted that, in the case of woody grasslands and wood in wetlands and settlements, if the dead organic matter pool is included in the living biomass pool, the changes in those pools could alternatively be reported as “IE” instead of “NO”. The present ERT also noted that “NO” is reported for emissions from biomass burning for all categories except forest land and settlements. The ERT recommends that Germany examine all cases where “NO” is reported in the LULUCF sector, and provide a transparent explanation justifying the selection of the notation key. The ERT also reiterates the recommendation made in the previous review report that the Party use other notation keys, if appropriate.	§ 60	The notations keys were updated in the respective CRF tables 5.B - 5.F. The information is given in the NIR chapters (e.g. chapter 7.3.4.2).	NIR 2014 chapter 7.3.4.2

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5.	In response to questions raised by the ERT during the review, the Party explained that new data from BWI III (2012) will provide updated values for biomass increment in land converted to forest land for the period 2002–2012, and that the data will be used in the 2015 annual submission. The Party also explained that in future inventories the values for 2008 onwards for dead wood in forest land remaining forest land will be recalculated, allowing a comparable calculation using the Inventory Study (2008) and BWI III (2012). The ERT welcomes the planned improvements and reiterates the recommendation made in the previous review report that, in order to ensure time-series consistency, Germany evaluate the inventory methodologies with regard to the use of data from a variety of sources that differ in their coverage and methods, and transparently document how the time-series consistency issues have been addressed.	§ 62	In the chapter 7.1.3.2.1 more description is given.	NIR 2014 chapter 7.1.3.2.1
5.	Germany has provided information on QA/QC in the NIR. The NIR refers to tier 1 and tier 2 QA/QC procedures being implemented for the LULUCF sector in accordance with the provisions of the QSE manual and associated documents. However, aside from the comparison of the Party's IEFs with those of other European countries, the NIR lacks transparent information on category-specific QC checks for different land-use categories. The ERT reiterates the recommendation made in the previous report that Germany provide more detailed, transparent information on the category-specific QC checks performed for all categories in the LULUCF sector.	§ 63	The chapter 7.1.8 und the subchapters of the different land-use categories were updated.	NIR 2014 chapter 7.1.8
5.A.2	Carbon stock changes in the litter pool for land converted to forest land were estimated on the basis of measured data from BZE I, BZE II and the BioSoil inventory. According to the information available from these inventories, two mean carbon stocks in litter were used, one referenced to 1990 (BZE I) and a second referenced to 2006 (BZE II/BioSoil). For the period 1991 to 2005, the mean carbon stocks in litter were obtained via interpolation; for the period as of 2007 they were obtained via extrapolation and used as a basis for calculating afforestation areas. According to the NIR, the annual carbon stock increase in litter was obtained by dividing the mean carbon stocks for the year in question by the number of years required for those mean carbon stocks to form. Germany assumed that it takes 40 years for average carbon stocks to form in litter. This methodology is different from the default methodology for the estimation of annual change in carbon stocks in litter provided in the IPCC good practice guidance for LULUCF. The NIR contains no explanation for the assumption regarding the time required for carbon stocks to form in litter and there is insufficient description of the methodology used for the estimation of carbon stock change in litter and its consistency with the methodology provided in the IPCC good practice guidance for LULUCF. In response to a question raised by the ERT during the review, Germany explained that the 40-year value used was obtained as an average, taking into consideration the IPCC good practice guidance for LULUCF values for the different species composition in German forests. The ERT recommends that the Party include the information on the average time used in the NIR and reiterates the recommendation made in the previous review report that Germany transparently describe the methodology, clearly demonstrating its consistency with the methodology provided in the IPCC good practice guidance for LULUCF to improve transparency.	§ 64	More information is given under the chapter 7.2.4.3	NIR 2014 chapter 7.2.4.3
5.D	Carbon stock changes in wetlands are reported using two subcategories: terrestrial wetlands and water bodies. In response to a question raised by the ERT during the review, Germany explained that the subcategory terrestrial wetlands consists of wetlands on undrained mineral soils and on organic soils. The organic soils are also divided between undrained and drained areas. The drained area is used for peat extraction, which is reported in the country-specific category terrestrial wetlands remaining terrestrial wetlands. In response to the recommendation made in the previous review report, Germany included in the NIR information on the methodology followed and EFs used, particularly for organic soils in peat extraction areas. The ERT welcomes this improvement and reiterates the recommendation made in the previous review report that Germany report the emissions and removals from wetlands according to the wetlands subcategories defined in the IPCC good practice guidance for LULUCF.	§ 65	In submission 2014 the subcategories are restructured according the ERT recommendations, chapter 7.5.3 was updated see picture 66a.	NIR 2014 chapter 7.5.3 was updated see picture 66a.
6.A	According to the NIR, there are no official statistics on biodegradable waste fractions for 2011 and therefore the Party has assumed that the waste quantities remained unchanged with respect to 2010. However, the ERT noted that in the NIR (table 292), different values for landfilled garden and park waste were reported for 2010 (1 kt) and 2011 (0 kt). In response to a question raised by the ERT during the review, the Party explained that there was a transcription error from the calculation file to the NIR. The ERT recommends that Germany correct the value and strengthen its QC activities to avoid such errors.	§ 67	Value has been corrected. Reason for this failure was a rounding error, that can occur.	

Member State: Germany

Reporting year: 2013 -- Implementation of ARR 2014 was not possible due to considerable delay of the finalized version until 28.04.2015!

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
6.B.1	The Party included in the 2013 annual submission estimates of N2O emissions from industrial wastewater for the first time. The emissions have been estimated based on annual N loads (2.0 to 2.5 per cent of the chemical oxygen demand (COD) concentration) for the four industries that account for 68 per cent of N load from industrial wastewater. The ERT commends Germany for its effort to estimate N2O emissions from industrial wastewater and encourages the Party to determine the COD values for the other industry-specific wastewater streams.	§ 70	Issue has been resolved. Sugarproduction and WheatStarchproduction have been additionally estimated with the 2015 Reporting. Germany now estimates six industrial branches that account for 75 per cent of N load from industrial wastewater. The Guidelines require only 4 industrial branches.	NIR 2015 Chapter 7.3.1.2.2.
6.B.2	The Party used the IPCC default methane conversion factor (MCF) for septic systems (0.5) and explained in the NIR that studies are going on to determine a country-specific value. In response to a question raised by the ERT during the review, the Party explained that for the next annual submission, it has adjusted its MCF to 0.173 in order to reflect country-specific conditions. The ERT commends the Party for the development of a country-specific MCF and recommends that Germany use the adjusted MCF.	§ 69	MCF has been adjusted to reflect country-specific conditions. See NIR Chap. 8.3.2.1.2	NIR 2014 Chap. 8.3.2.1.2
6.B.2	According to the NIR, one of the ways to manage sewage sludge from biological wastewater treatment is recycling for substance recovery, and these emissions are reported in the agriculture sector in line with the IPCC good practice guidance. The ERT reiterates the encouragement made to the Party in the previous review report to include in the NIR more information on the use of sewage sludge from biological wastewater treatment in order to improve the transparency of its reporting.	§ 71	Table showing the breakdown of substance recovery and use of sewage sludge from biological wastewater treatment is provided in the NIR. See NIR Chap. 8.3.2.2.1, Table 324	NIR 2014 See NIR Chap. 8.3.2.2.1, Table 324
6.C	The Party used the notation key “NO” in CRF table 6.C to report AD and emissions from waste incineration. According to the NIR, all waste incineration facilities in Germany produce electricity and/or heat and, therefore, emissions were reported in the energy sector under public electricity and heat production. The ERT recommends that Germany improve transparency by providing, in the NIR chapter on waste incineration, a reference to the relevant NIR chapter in the energy sector, in which more information on incineration plants in the country is provided.	§ 72	Reference to the relevant NIR chapter in the energy sector has been added. Chapter 8.4	NIR 2014 Chapter 8.4
6.D.(b)	The ERT noted that the explanations in the NIR on mechanical-biological waste treatment (MBT) are very limited and ambiguous. The ERT reiterates the recommendation made in the previous review report that Germany provide further information in the NIR on the range of techniques employed in MBT processes (how MBT works and inputs and outputs of waste) and on the correlation of MBT processes with emissions from different subcategories of the waste sector in order to improve the transparency of its reporting.	§ 68	NIR chapter was comleted with the required information. Chapter 8.5.2	NIR 2014 Chapter 8.5.2
KP	Notation keys in the KP-LULUCF CRF tables were used inconsistently between different tables. In CRF table NIR-1, the notation key “R” (reported) is used for CO2 emissions from liming in afforestation and reforestation land in 2011. In CRF table 5(KP- II)4 the notation keys used are “IE”, “NO”. In CRF table NIR-1, notation key “R” is used for reporting CO2, CH4 and N2O emissions from biomass burning in afforestation and reforestation land in 2011. In CRF table 5(KP-II)5 the notation keys used are “NO”, “IE”. The ERT recommends that Germany use the correct notation keys in CRF table NIR-1.	§ 76	Correction of the notation keys in the CRF tables.	- -

Member State: Germany

Reporting year: 2013 -- Implementation of ARR 2014 was not possible due to considerable delay of the finalized version until 28.04.2015!

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
KP	The ERT concluded that, taking into account the confirmed changes in the national registry, including additional information provided to the ERT during the review, Germany's national registry continues to perform the functions set out in the annex to decision 13/CMP.1 and the annex to decision 5/CMP.1 and continues to adhere to the technical standards for data exchange between registry systems in accordance with relevant decisions of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol. With respect to the provision of information related to database structure specifically, the ERT encourages the Party to provide additional information in the NIR. The ERT recommends that Germany include all other additional information in response to the SIAR findings in its NIR in accordance with decision 15/CMP.1, annex, chapter I.G.	§ 86	Germany is continuing to work on that issue.	
KP	Germany did not provide information on changes in its reporting of the minimization of adverse impacts in accordance with Article 3, paragraph 14, of the Kyoto Protocol in its annual submission. In response to a question raised by the ERT during the review, the Party confirmed that there are no changes between the activities reported in the 2012 and 2013 annual submissions (except a minor editorial change). The ERT concluded that the information in the annual submission was not complete, but taking into account the clarification from the Party, the information provided is complete and transparent. The ERT recommends that the Party report any changes in the information provided under Article 3, paragraph 14, in accordance with decision 15/CMP.1, annex, chapter I.H.	§ 87	Germany is continuing to work on that issue.	

11 SUPPLEMENTARY INFORMATION REQUIRED UNDER ARTICLE 7, PARAGRAPH 1 OF THE KYOTO PROTOCOL

11.1 General information

11.1.1 The definition of forest, and any other criteria

The National Forest Inventory is the main data source used for determination of activity data and emission factors. Its forest definition, which serves as a basis for the report, is presented in Chapter 6.2.1.

In keeping with Germany's initial report under the Kyoto Protocol (UNFCCC 2007), Germany has defined the following specific parameters for its national forest definition:

Table 343: Definition of "forest" in Germany

Parameter	Range	Selected value
Minimum area of land	0.05 – 1.00 ha	0.1 ha
Tree crown cover or equivalent stocking level	10 – 30 %	(10 %)
Potential tree height at maturity	2 – 5 m	5 m

Within the range defined by the Marrakesh Accords (c.f. the above range), these parameters are the ones that come closest to the definition used in the National Forest Inventory. As comparative studies have shown, the differences between different activity-data calculations carried out in accordance with the aforementioned parameters are negligible.

The first National Forest Inventory does not include data for the new German Länder. The project GSE Forest Monitoring (GSE 2003, GSE 2006, GSE 2007, GSE 2009) was carried out to compensate for that gap. Working on the basis of maps, it determined forest cover, and its changes, between 1990 and 2002 and between 1990 and 2005/2006. The forest definition used within GSE was based on the internationally accepted definition of the FAO, however, which specifies a minimum area of land of 0.5 ha (cf. also OEHMICHEN et al. (2011b)). The original data available to the Thünen Institute (TI) include land areas and land-use changes smaller than the 0.5 ha threshold, and down to a pixel size of 25m x 25m. Such smaller units may be considered similar to the "minimum mapping units" used in the National Forest Inventory (cf. also Chapter 6.3.1.2).

Pursuant to UNFCCC (1998), areas are to be assigned to the activities "afforestation" and "deforestation" if they have been afforested / deforested since 1990. Such areas remain in those assigned categories until the end of the commitment period. As a result, the areas of said categories increase constantly. In the context of greenhouse-gas reporting, short-rotation plantations are not included as forest (cf. Chapter 6.3.1.2), and are reported under cropland.

In general, reforestation requirements apply in Germany (cf. Art. 11 (1) p. 2 Federal Forest Act (BWaldG), meaning that clear-cut forest areas and thinned forest stands have to be reforested or replenished. Areas that have been afforested since 1990, but temporarily have no forest cover as a result of natural disasters, continue to fall within the definition of forest and must be reforested. No deforestation as a result of natural disasters takes place in Germany.

11.1.2 Elected activities under Article 3 Paragraph 4 of the Kyoto Protocol

In the second commitment period, Germany has to carry out accounting for its forestry activities (*forest management*) pursuant to Article 3 (4) of the Kyoto Protocol. In addition, Germany is reporting emissions from harvested wood products. Germany has not selected the option *natural disturbances*.

Germany has selected the following voluntary activities under Article 3.4 of the Kyoto Protocol:

- Cropland management (CM)
- Grazing land management (GM).

Germany has opted for accounting at the end of the second commitment period.

11.1.3 Description of how the definitions of each activity under Article 3.3, and each elected activity under Article 3.4, have been implemented and applied consistently over time

11.1.3.1 Afforestation, reforestation and deforestation (ARD)

The definitions used by Germany for afforestation, reforestation and deforestation are in accordance with the Marrakesh Accords (MA). Pursuant to the MA, afforestation is defined as "the direct human-induced conversion of land that has not been forested for a period of at 50 years to forested land through planting, seeding and / or the human-induced promotion of natural seed sources[138]." Reforestation differs from afforestation solely with regard to the time since the area was last forested and, pursuant to the IPCC, occurs on land that has not been forest since 31 December 1989[139]. Since the reporting period for Germany begins with base year 1990, and since adequate data for differentiation of land-use forms are available only for the period as of 1970, afforestation and reforestation are considered together in the present context (and hereafter are both referred to as afforestation). Afforestation means the establishment of trees on abandoned land, if the relevant rejuvenation suffices for producing forest in accordance with the national forest definition. In general, the time of afforestation is the time at which the first activity in the relevant regeneration process was carried out. In the case of spontaneous regeneration of trees, the time of afforestation is considered to be the time at which the national criteria for the forest definition have been met, i.e. when the natural forest cover has reached an average age of five years, and a crown cover of at least 50 % (cf. Chapter 6.2.1).

The afforestation category corresponds to the following categories in reporting under the UN Framework Convention on Climate Change:

[138] Annex A Paragraph 1 lit. b to Decision 16/CMP.1 (FCCC/KP/2005/8/Add.3, page 5).

[139] Original: "Reforestation" is the direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources, on land that was forested but that has been converted to non-forested land. For the first commitment period, Reforestation activities will be limited to Reforestation occurring on those lands that did not contain forest on 31 December 1989. (IPCC KP Supplements (2014))

Table 344: Afforestation in KP and UNFCCC categories

Category for KP reporting	Category pursuant to UNFCCC	
Afforestation under Art. 3.3 KP	4.A.2.1 Cropland converted to forest land	
	4.A.2.2. Grassland converted to forest land	4.A.2.2.1 Grassland (in a strict sense – i.t.s.s.) converted to forest land
		4.A.2.2.2 Woody grassland converted to forest land
	4.A.2.3. Wetlands converted to forest land	4.A.2.3.1 Wetlands (terrestrial) converted to forest land
		4.A.2.3.2 Waters converted to forest land
	4.A.2.4. Settlements converted to forest land	
	4.A.2.5. Other land converted to forest land	

The IPCC defines deforestation as "the direct human-induced conversion of forested land to non-forested land"[140]. In accordance with the provisions of the IPCC, harvest that is followed by regeneration is not considered deforestation, since harvest is a forest-management activity pursuant to Art. 3.4. This definition does not include "forest cover loss resulting from natural disturbances, such as wildfires, insect epidemics or wind storms", since "in most cases these areas will regenerate naturally or with human assistance". Such areas also fall within the category of managed land pursuant to Art. 3.4 or, if the areas are afforested land, within the category of afforested land pursuant to Art. 3.3.

Where, since 1990, human activities have taken place on such areas temporarily without forest cover – activities such as road construction, settlement construction or other forms of land use (management of grassland or wetlands) – with the result that forest regeneration is prevented, then, so the IPCC, the areas must be considered deforested.

The afforestation category corresponds to the following categories in reporting under the UN Framework Convention on Climate Change:

Table 345: Deforestation in KP and UNFCCC categories

Category in KP reporting	Category pursuant to UNFCCC	
Deforestation under Art. 3.3 KP	4.B.2.1. Forest land converted to cropland	
	4.C.2.1. Forest land converted to grassland	4.C.2.1.1 Forest land converted to grassland (i.t.s.s.)
		4.C.2.1.2 Forest land converted to woody grassland
	4.D.2.1. Forest land converted to wetlands	4.D.2.1.1 Forest land converted to wetlands (terrestrial)
		4.D.2.1.2 Forest land converted to waters
	4.E.2.1. Forest land converted to settlements	
	4.F.2.1. Forest land converted to other land	(NO)

NO: not occuring

140 Annex A No 1 lit. d FCCC/CP/2001/15/Add.1, page 58.

11.1.3.2 Forest management (FM)

In Germany, all forest areas that have been forest since 1990 are considered managed within the meaning of the Marrakesh Accords[141] and are reported under *forest management*[142] pursuant to Art. 3.4 KP. A detailed pertinent description is presented in Chapter 10.5.1.

Table 346: Forest management in KP and UNFCCC categories

Category in KP reporting	Category pursuant to UNFCCC
Forest management pursuant to Art. 3.4 KP	4.A.1 Forest land remaining forest land

Since every land-use change to forest is considered afforestation, every land-use change from forest land to a different land-use category is considered deforestation, and all forest areas not afforested are subject to forest management, there is no possibility that the manner in which the relevant definitions are applied could change over time.

The emissions contribution from harvested wood products in Germany, in terms of greenhouse emissions from sources and removals in sinks, in the land-use sector, was estimated with the help of the WoodCarbonMonitor model, via a calculation approach based on wood-product production data. The estimate covers all wood products that are produced in Germany, that consist of wood that originates from trees harvested in Germany and that are used for their material (not energy) value.

11.1.3.3 Cropland management (CM)

Cropland management (CM) is agricultural use of land for cultivation of field crops (such as grain, pulses, root crops) and berries (such as strawberries); of garden land for cultivation of vegetables, fruit and flowers and for culturing of crops; and of special crop areas, for cultivation of certain plants (such as hops, wine grapes, fruit in orchards). Cropland management includes annual crops and permanent crops such as wine grapes, fruit trees, Christmas trees and short-rotation plantations. Permanent crops do not fall within the German definition of forest.

The definition of cropland management is in keeping with the definition of areas under cropland as used for reporting under the UN Framework Convention on Climate Change (cf. Chapter 6.2 and Table 270).

The afforestation category corresponds to the following categories in reporting under the UN Framework Convention on Climate Change:

[141] Paragraph 1 lit. f of Annex A of Decision 16/CMP.1

[142] Original: "'Forest management' is a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner." (IPCC KP Supplements (2014))

Table 347: Afforestation in KP and UNFCCC categories

Category in KP reporting	Category pursuant to UNFCCC	
Cropland management pursuant to Art. 3.4 KP	4.B.1 Cropland remaining cropland	
	4.B.2.2 Grassland converted to cropland	4.B.2.2.1 Grassland (in a strict sense) converted to cropland
		4.B.2.2.2 Woody grassland converted to cropland
	4.B.2.3 Wetlands converted to cropland	4.B.2.3.1 Wetlands (terrestrial) converted to cropland
		4.B.2.3.2 Waters converted to cropland
	4.B.2.4 Settlements converted to cropland	
	4.B.2.5 Other areas converted to cropland	
	4.C.2.2.2 Cropland converted to woods[1)]	
	4.D.2.2 Cropland converted to wetlands[2)]	4.D.2.2.3 Cropland converted to terrestrial wetlands[3)]
		4.D.2.2.2 Cropland converted to wetlands[4)]
	4.E.2.2 Cropland converted to settlements[5)]	
	4.F.2.2 Cropland converted to other areas (NO)[6)]	

Numbers: 1), 2), 3), 4), 5) emissions and removals are listed as zero (IPCC KP Supplement (2014) Chap. 2.9.2).
Footnote 6) NO: Not occurring

All areas under cropland management are subject to periodic cultivation measures, and thus the pertinent emissions and removals are anthropogenic.

11.1.3.4 Grazing land management (GM)

Grazing land management (GM) is the use of grassland in the strict sense as meadows, pastures, mountain pastures, rough pastures, heath land, natural grassland, recreational areas or swamps/marshes.

The definition of grazing land management is in keeping with the definition of areas under grassland (in the strict sense) as used for reporting under the UN Framework Convention on Climate Change (cf. Chapter 6.2 and Table 270).

The grazing land management category corresponds to the following categories in reporting under the UN Framework Convention on Climate Change:

Table 348: Grazing land management in KP and UNFCCC categories

Category in KP reporting	Category pursuant to UNFCCC	
Grazing land management pursuant to Art. 3.4 KP	4.C.1.1 Grassland (in the strict sense) remaining as Grassland (i.t.s.s.)	
	4.C.2.2.1 Cropland converted to grassland (i.t.s.s.)	
	4.C.1.3 Woody grassland converted to grassland (i.t.s.s.)	
	4.C.2.3.1 Wetlands converted to grassland (i.t.s.s.)	4.C.2.3.3.1 Terrestrial wetlands converted to grassland (i.t.s.s.)
		4.C.2.3.2.1 Waters converted to grassland (i.t.s.s.)
	4.C.2.4.1 Settlements converted to grassland (i.t.s.s.)	
	4.C.2.5.1 Other areas converted to grassland (i.t.s.s.)	
	4.C.1.4 Grassland (i.t.s.s.) converted to woody grassland[1)]	
	4.D.2.3 Grassland (i.t.s.s.) converted to wetlands[2)]	4.D.2.3.1.3 Grassland (i.t.s.s.) converted to terrestrial wetlands[3)]
		4.D.2.3.1.2 Grassland (i.t.s.s.) converted to waters[4)]
	4.E.2.3.1 Grassland (i.t.s.s.) converted to settlements[5)]	
	4.F.2.3.1 Grassland (i.t.s.s.) converted to other areas[6)]	

Numbers 1), 2), 3), 4), 5) emissions and removals are listed as zero (IPCC KP Supplement (2014) Chap. 2.9.2).
Footnote 6) NO: Not occurring

All areas under grazing land management are subject to periodic cultivation measures, and thus the pertinent emissions and removals are anthropogenic.

11.1.4 Description of precedence conditions and/or hierarchy among Article 3.4 activities, how they have been consistently applied in determining how land was classified

Germany has defined the hierarchy of activities relative to Art. 3.4 of the Kyoto Protocol pursuant to the provisions of the IPCC KP Supplement (2014). The activity *forest management* is binding, and thus has priority over the voluntary activities *cropland management* and *grazing land management*. In the first commitment period, Germany selected *forest management* voluntarily. The hierarchy makes it possible to carry out consistent reporting for the first and second commitment periods.

Pursuant to the provisions of the IPCC KP Supplements (2014), forest management (FM) can take place only on lands that meet the definition of forest. The forest areas reported under FM are the forest areas reported, pursuant to the Convention, under *forest land remaining forest land*, except for areas assigned either to the categories of conversion leading to forest land (Convention) or to the category of afforestation (Kyoto Protocol). The total forest area under the Convention and the total forest area under the Kyoto Protocol are the same. All German forest lands are considered managed within the meaning of the provisions of the Marrakesh Accords. The definition of forest management is broadly interpreted (cf. for a detailed discussion Chapter 11.5.1).

Within the group of voluntary activities, allocations to *cropland management* have priority over allocations to *grazing land management*. Agricultural grass within the context of crop rotations is allocated to cropland management. By contrast, permanent land-use changes from cropland to grassland (in the strict sense), and vice-versa, are reported as activity changes from cropland management to grazing land management, and vice-versa. As a result, the land classifications for cropland management and grazing land management are in keeping with the inventory's classifications of cropland and grassland (in the strict sense) under the UNFCCC.

11.2 Land-oriented information

11.2.1 Spatial assessment unit used for determining the area of the units of land under Article 3.3

The method used to derive activity data (areas) is described in Chapter 6.3. It corresponds to Approach 3 pursuant to the IPCC 2006 Guidelines. The reference area is Germany; it comprises 35,779.63 kha. The areas in the "forest" land-use categories, and their additions and removals, are derived primarily from the point data of the National Forest Inventories (BMELV 2005). For the new German Länder, the National Forest Inventory (BWI) data have been supplemented with data from the project GSE FM-INT (GSE 2003, GSE 2006, GSE 2007, GSE 2009) (cf. also Chapters 6.4.2.1 and 6.2). A detailed description of land-use-classification procedures is provided in Chapter 6.2, while a description of the procedures for derivation of the land-use matrix (LUM) is provided in Chapter 6.3.

Thanks to the use of a consistent method for derivation of the LUM, the same spatial assessment unit is used for deforestation areas as is used for afforestation areas.

11.2.2 Method used to develop the land-transition matrix

The method used to define forest areas, and to derive areas for the "change" classes, is described in detail in Chapter 6.3. Table 349 provides an overview of land-use changes leading to forest land (afforestation), of land-use changes leading away from forest land (deforestation), and of managed areas (forest management) for the period 1990 to 2013. Conversion areas remain in the conversion category until the end of the 2nd commitment period of the Kyoto Protocol, 2020; for this reason, the annual areas accumulate. In Table 349, the column for the accumulated areas lists those areas as they are reported. An adjacent column shows the corresponding annual areas.

Table 349: Areas in the categories afforestation, deforestation and forest management, 1990 to 2013

Year	Afforestation/ Reforestation (KP 3.3) [kha]		Deforestation (KP 3.3) [kha]		Forest Management (KP 3.4) [kha]	
	Accumulated areas	Annual areas	Accumulated areas	Annual areas	Accumulated areas	Annual areas
1990	28.026	28.026	12.483	12.483	11,126.599	11,126.599
1991	56.053	28.026	24.966	12.483	11,114.116	11,142.143
1992	84.079	28.026	37.449	12.483	11,101.633	11,157.686
1993	112.106	28.026	49.932	12.483	11,089.150	11,173.230
1994	140.132	28.026	62.414	12.483	11,076.668	11,188.773
1995	168.159	28.026	74.897	12.483	11,064.185	11,204.317
1996	196.185	28.026	87.380	12.483	11,051.702	11,219.860
1997	224.211	28.026	99.863	12.483	11,039.219	11,235.404
1998	252.238	28.026	112.346	12.483	11,026.736	11,250.947
1999	280.264	28.026	124.829	12.483	11,014.253	11,266.491

Year	Afforestation/ Reforestation (KP 3.3) [kha]		Deforestation (KP 3.3) [kha]		Forest Management (KP 3.4) [kha]	
	Accumulated areas	Annual areas	Accumulated areas	Annual areas	Accumulated areas	Annual areas
2000	308.291	28.026	137.312	12.483	11,001.770	11,282.035
2001	322.412	14.122	146.620	9.308	10,992.462	11,300.753
2002	336.534	14.122	155.928	9.308	10,983.154	11,305.566
2003	350.656	14.122	165.237	9.308	10,973.845	11,310.379
2004	364.777	14.122	174.545	9.308	10,964.537	11,315.193
2005	378.899	14.122	183.853	9.308	10,955.229	11,320.006
2006	393.425	14.526	195.125	11.272	10,943.957	11,322.856
2007	407.951	14.526	206.397	11.272	10,932.685	11,326.110
2008	422.477	14.526	217.669	11.272	10,921.413	11,329.364
2009	439.038	16.561	228.153	10.484	10,910.929	11,333.406
2010	455.599	16.561	238.637	10.484	10,900.445	11,339.483
2011	472.160	16.561	249.121	10.484	10,889.961	11,345.560
2012	488.722	16.561	259.605	10.484	10,879.477	11,351.637
2013	506.485	17.764	270.121	10.516	10,868.961	11,357.682

The method used to define cropland areas, and to derive areas for the "change" classes, is described in detail in Chapter 6.3. In Table X, the areas under cropland management are summarised for the base years 1990 and 2013. In the base years, the land-use changes in the period 1970 through 1990 are included, except those consisting of land-use changes leading to forest land. For purposes of methodological consistency with KP Art. 3.3, those changes have been recorded cumulatively, since 1990, as afforestation. The areas are divided into the categories

- Cropland remaining cropland
- Land-use changes leading to cropland (except for changes from forest land)
- Land-use changes from cropland to land-use categories that are not included in other activities under KP Art. 3.3. or 3.4.

In the case of land-use changes from cropland, and from grassland (in the strict sense), to land-use categories that are not included in other activities under KP Art. 3.3. or 3.4, the following procedure is used: in keeping with the IPCC KP Supplements (2014), Chap. 2.9.2, that area is reported that has been converted from cropland or grassland (in the strict sense) to other use categories. Pursuant to the IPCC KP Supplements (2014), Chap. 2.9.2, the emissions from those areas are listed as zero.

Table 350: Overview of areas under cropland management and grazing land management in the base years 1990 and 2013, as well as of areas that switch between activities under KP Art. 3.4 and 3.3

Sub-categories	Cropland management (CM)		Grazing land management (GM)	
	Area, 1990 [kha]	Area, 2013 [kha]	Area, 1990 [kha]	Area, 2013 [kha]
…land remaining …land	**12,584.315**	**12,365.027**	**5,742.447**	**5,077.170**
Land-use change from cropland (CM to GM)	IE	IE	627.428	477.028
Land-use change from grassland (in the strict sense) (GM to CM)	862.638	1,013.881	IE	IE
Land-use change from woody grassland	30.009	13.099	62.629	32.886
Land-use change from terrestrial wetlands	5.592	2.157	3.596	2.657
Land-use change from waters	12.719	5.151	44.191	27.944
Land-use change from settlements	69.087	49.826	104.196	93.576
Land-use change from other land	2.393	5.234	12.171	16.703
Total for LUC to …land	**982.438**	**1,089.347**	**854.210**	**650.795**
Land-use changes leading to woody grassland	64.467	65.278	21.125	62.248
Land-use changes leading to terrestrial wetlands	1.798	0.729	4.999	14.812
Land-use changes leading to waters	26.515	17.662	21.690	21.272
Land-use changes leading to settlements	364.504	541.502	172.777	240.454
Total for LUC from …land	**457.284**	**625.171**	**220.590**	**338.786**
Total	**14,024.037**	**14,079.546**	**6,817.248**	**6,066.751**
Afforestation since 1990 (reported under KP Art. 3.3)	9.699	168.095	11.465	213.508

11.2.3 Maps and/or databases to identify the geographical locations, and the system of identification codes for the geographical locations

The following data sources were used in determination of activity data:

- National Forest Inventory 1987 (Bundeswaldinventur; BWI 1987)
- National Forest Inventory 2002 (Bundeswaldinventur; BWI 2002)
- Inventory Study 2008 (Inventurstudie; IS08)
- National Forest Inventory 2012 (Bundeswaldinventur; BWI 2012)
- CIR data (maps produced in mapping of biotopes and usage types)
- GSE ForestMonitoring: Inputs for national greenhouse-gas reporting (GSE FM-INT)
- Official topographic-cartographic information system (Amtliches Topographisch-Kartographisches Informationssystem; ATKIS®)
- CORINE Land Cover (CLC)
- Soil map for the Federal Republic of Germany 1:1,000,000 (Bodenübersichtskarte der Bundesrepublik Deutschland; BÜK 1000)
- Forest-fire statistics of the Federal Republic of Germany

Detailed descriptions of the data sources are presented in Chapters 6.4.2.1 and 6.3.1.2.

All afforestation and deforestation are accounted for under Article 3.3 and are not listed under forest management, cropland management and grazing land management pursuant to Article 3.4. The changes in areas between the measures pursuant to Article 3.3 and to Article 3.4 are listed in KP table NIR 2. The method for deriving areas uses a sample-based system that records the area for each land-use category and the land-use changes to and from the various land-use categories. The sampling network used is based on the grid for the BWI 2012. Each sample point is proportionally assigned to the land-use categories forest management, afforestation and deforestation, cropland management and grazing land management. In the categories afforestation and deforestation, no changes of pertinent sample-point proportions into other land-use categories can take place. Each proportion of a sample point corresponds to an area. Such an area's geographic position is determined in terms of the pertinent sample-point coordinates. This identification system ensures that differentiation between a) afforested and deforested areas under Article 3.3 and b) forest management, cropland management and grazing land management areas under Article 3.4 is unambiguous.

11.3 Activity-specific information

11.3.1 Methods for carbon stock change, greenhouse gas emission and removal estimates

11.3.1.1 Description of methodologies and the underlying assumptions used

11.3.1.1.1 Summary

Most of the descriptions of methods are presented in Chapter 3, which discusses the issue of reporting for the UN Framework Convention on Climate Change.

Forest management and afforestation

As described in Chapter 11.1.3, the categories forest management and afforestation in the Kyoto Protocol are equivalent to the UNFCCC categories 5.A.1 Forest Land remaining Forest Land and 5.A.2 Land converted to Forest Land, respectively. For this reason, in the following chapters methodological information relative to these categories is usually provided via referencing to Chapter 6; additional methodological descriptions are provided largely only for the area of deforestation.

Deforestation

For the period 1987 to 2002 in the old German Länder, and for the period 2002 to 2012 in all German Länder, up-scaling was carried out for this category on the basis of individual-tree data from the National Forest Inventories and from the Inventory Study (samples, Tier 2). In addition, the biomass C stocks for deforested areas were estimated (cf. Chapter 11.3.1.1.2). The C stocks of the old German Länder, in this category for the period from 1987 to 2002, were applied to the "forest land converted to other land" areas in the new German Länder, since the Datenspeicher Waldfonds forest database does not provide any information in this regard. For the year 2013, the results for the period 2002 through 2012 are carried forward. All in all, carbon stocks of some -54.66 Mg C ha^{-1} were lost from biomass (not including the biomass of the converted land) via deforestation in 2013. As a simplification, it was assumed that C stocks are emitted into the atmosphere in the year in which the land was converted.

The implied emission factors derived from biomass losses, and from the areas calculated for each relevant year since 1987, decreased continuously, for purposes of reporting under the Kyoto Protocol, from 1990 to 2013. This is due solely to the fact that the relevant areas remain in the deforestation category as of 1990, with the result that the total area increases in each report year. Table 351 illustrates this effect with the example of decreasing above-ground biomass in connection with deforestation. Along with decreasing biomass, increasing biomass in the new land-use category has to be taken into account. Such increasing biomass is offset against the relevant decreasing biomass.

Table 351: Annual and accumulated deforested areas, and annual and implied emission factors for decreasing above-ground forest biomass; positive: C sink; negative: C emissions

	1990	2000	2010	2013
Area of annual deforestation [ha]	12,483	12,483	10,484	10,516
Annual emission factor [Mg C ha^{-1}]	-24.53	-24.53	-46.48	-46.48
Accumulated deforested area [ha]	12,483	137,312	238,637	270,121
Implied emission factor [Mg C ha^{-1}]	-24.53	-2.23	-2.04	-1.81

In addition to losses of biomass in connection with conversion of forest land, other types of losses must be considered as well, including losses in the areas of dead wood, litter, mineral soils and organic soils. In the case of biomass, dead wood and litter, it is assumed that the pertinent losses take the form of emissions in the year of conversion. Emissions from organic soils take place each year on the entire deforested area. For mineral soils, a transition time of 20 years is assumed.

An overview of the carbon losses from deforestation, and from deforestation areas, for the year 2013 is provided in Table 352.

Table 352: Deforested areas and deforestation-related carbon-stock losses from biomass (including the biomass of the converted land), dead wood, litter and mineral and organic soils, for the year 2013; positive: C sink; negative: C emissions

Pool	Carbon-stock loss [GgC] 2013
Biomass	-434.729
Dead wood	-20,881
Litter	-196.789
Mineral soils	27.648
Organic soils	-108.436
Total	**-733.186**
	Deforested area [ha]
Annual	10,516
Accumulated	270,121

<u>Cropland management</u>

Methodologically, the activity cropland management corresponds to the UNFCCC categories 4.B.1 and 4.B.2, with the exception of 4.B.2.1 Forest land converted to cropland. In keeping with the *IPCC KP Supplements* IPCC 2014, Chap. 2.9.2, emissions and removals on areas converted from cropland to non-accounted land-use categories are accounted as zero. The relevant calculation methods are as follows:

- Changes in carbon stocks in above-ground and below-ground biomass: Chapter 6.5.2.1,
- Carbon-stocks change in mineral soils: Chapter 6.5.2.2,
- CO_2, CH_4 and N_2O emissions from drained organic soils: Chapter 6.5.2.3,
- Direct and indirect N_2O emissions from humus losses connected to land-use changes: Chapter 6.1.2.1.2

The carbon pools dead wood and litter occur only on forest land; they do not occur in cropland management (NO), since land-use changes from forest land to cropland are accounted under deforestation. N_2O emissions from organic soils under cropland are reported not under the cropland management activity pursuant to Art. 3.4, but as part of the agricultural sector.

Table 353 provides an overview for 2013 of carbon-stock changes, and of greenhouse-gas emissions, in connection with cropland management.

Table 353: Carbon-stock and greenhouse-gas emissions as a result of cropland management, for the year 2013

Sub-categories	**C-stock changes in biomass, 2013[143]**	**C-stock changes in mineral soils, 2013[79]**	**CO_2 from organic soils, 2013[79]**	**CH_4 from organic soils, 2013[144]**	**Direct and indirect N_2O from decomposition of organic material in mineral soils, 2013[80]**	**Total, 2013[80/145]**
	[Gg C]	**[Gg C]**	**[Gg C]**	**[Gg CH_4]**	**[Gg N_2O]**	**[Gg CO_2-eq.]**
Cropland remaining cropland	0	0	-2,179.06	6.99	0	8,164.76
Land-use change from grassland (in the strict sense) (GM to CM)	63.79	-826.17	-521.72	1.67	1.25	5,123.91
Land-use change from woody grassland	-24.99	-8.42	-2.38	0.01	0.01	135.38
Land-use change from terrestrial wetlands	0.00	-1.51	0.00	0.00	0.00	6.08
Land-use change from waters	0.00	0.00	0.00	0.00	0.00	0.00
Land-use change from settlements	-8.40	2.27	-131.62	0.42	0.00	515.63
Land-use change from other land	0.00	1.16	0.00	0.00	0.00	-4.25
Total for LUC to cropland	**30.40**	**-832.67**	**-655.73**	**2.10**	**1.27**	**5,776.76**
Total for LUC from cropland	**0**	**0**	**0**	**0**	**0**	**0.00**
Total	**30.40**	**-832.67**	**-2,834.79**	**9.10**	**1.27**	**13,941.51**

The emissions from cropland management in 2013 are dominated by CO_2 from organic soils. Carbon losses from mineral soils, as a result of conversions of grassland (in the strict sense) to cropland, are also significant.

In 2013, the net emissions from cropland management were lower than they were in the base year 1990 (cf. Table 364a), with the result that a net emissions reduction of -1,399.68 Gg CO_2-eq. can be credited in 2013. The majority of that reduction is due to decreases in cropland areas on organic soils, as well as to reduced land-use changes from settlements to cropland on organic soils. These effects more than offset the higher emissions resulting from increased land-use changes from grassland (in the strict sense) to cropland.

Greenhouse-gas emissions and removals from land-use changes from cropland to activities that are not accounted (terrestrial wetlands, waters, settlements) are reported, pursuant to *IPCC KP Supplements* IPCC 2014, Chap. 2.9.2, as zero. Consequently, no pertinent emissions have been reported. Emissions from the 20-year transition categories from cropland to these land-use categories in 2013, categories which cover the period 1994 – 2013, can provide an order-of-magnitude figure for the net emissions from these areas, however. In 2013, they amounted to a net sink of about -230 Gg CO_2-eq. The main reason for this was that emissions

[143] Stock change, positive: C sink; negative: C source

[144] GHG emissions, positive: GHG source; negative: GHG sink

[145] N_2O emissions from organic soils under cropland are reported as part of the agricultural sector

from organic soils, following land-use changes to settlements, were more than offset by a net CO_2 sink in the biomass. In the base year 1990, the net sink, from the same land-use changes, amounted to -323 Gg CO2-eq.

Grazing land management:

Methodologically, the activity grazing land management corresponds to the sub-categories of grassland (in the strict sense) (4.C.1.1 and land-use changes to grassland (in the strict sense), except for changes from forest land to grassland (in the strict sense)). In keeping with the *IPCC KP Supplements* IPCC 2014, Chap. 2.10.2, emissions and removals on areas converted from grassland (in the strict sense) to non-accounted land-use categories are accounted as zero. The relevant calculation methods are as follows:

- Changes in carbon stocks in above-ground and below-ground biomass: Chapters 6.6.2.2, 6.6.2.3,
- Carbon-stocks change in mineral soils: Chapter 6.6.2.3,
- CO_2, CH_4 and N_2O emissions from drained organic soils: Chapter 6.6.2.4,
- Direct and indirect N_2O emissions from humus losses connected to land-use changes: Chapter 6.1.2.1.2

The carbon pools dead wood and litter occur only on forest land; they do not occur in grazing land management (NO), since land-use changes from forest land to grassland (in the strict sense) are accounted under deforestation.

Table 354 provides an overview for 2013 of carbon-stock changes, and of greenhouse-gas emissions, in connection with grazing land management. N_2O emissions from organic soils under cropland are reported not under the grazing land management activity pursuant to Art. 3.4, but as part of the agricultural sector.

Table 354: Carbon-stock and greenhouse-gas emissions as a result of grazing land management, for the year 2013

Sub-categories	C-stock changes in biomass, 2013[146] [Gg C]	C-stock changes in mineral soils, 2013[82] [Gg C]	CO_2 from organic soils, 2013[82] [Gg C]	CH_4 from organic soils, 2013[147] [Gg CH_4]	Direct and indirect N_2O from decomposition of organic material in mineral soils, 2013[83] [Gg N_2O]	Total, 2013[83/148] [Gg CO_2-eq.]
Grassland (in the strict sense) remaining as Grassland (i.t.s.s.)	0	0	-5,561.55	17.29	0	20824.50
Land-use change from cropland (CM to GM)	-17.62	338.88	-600.18	1.87	0	1069.33
Land-use change from woody grassland	-18.26	4.94	-66.22	0.21	0	296.78
Land-use change from terrestrial wetlands	-2.43	0.30	-6.33	0.02	0	31.52
Land-use change from waters	4.00	0.00	-74.60	0.23	0	264.65
Land-use change from settlements	-9.80	70.68	-124.80	0.39	0	244.07
Land-use change from other land	0.00	18.23	0.00	0.00	0	-66.84
Total for LUC to grassland (in the strict sense)	**-44.10**	**433.02**	**-872.12**	**2.71**	**0**	**1839.50**
Total for LUC from grassland (in the strict sense)	**0**	**0**	**0**	**0**	**0**	**0**
Total	**-44.10**	**433.02**	**-6433.68**	**20.00**	**0.00**	**22664.00**

Almost all of the emissions from grazing land management in 2013 come from drained organic soils. Those emissions are slightly offset by the carbon sink resulting in mineral soils following land-use changes.

In 2013, the net emissions from grazing land management were higher than they were in the base year 1990 (cf. Table 364b), with the result that a net emissions increase of +1,607 Gg CO_2-eq. has to be credited in 2013. For the most part, those emissions are the result of increases in grassland areas on organic soils, and they more than offset the lower emissions resulting from decreases in land-use changes to grassland (in the strict sense).

Greenhouse-gas emissions and removals from areas with land-use changes to activities that are not accounted (terrestrial wetlands, waters, settlements) are reported, pursuant to the IPCC KP Supplements (2014), Chap. 2.10.2, as zero. Consequently, no pertinent emissions have been reported. Emissions from the 20-year transition categories from grassland (in the strict sense) to these land-use categories in 2013, categories which cover the period 1994 – 2013, can provide an order-of-magnitude figure for the net emissions from these areas, however. In 2013, they amounted to a net source of 492 Gg CO_2-eq.. The primary reason for this was that emissions from mineral and organic soils, following land-use changes to settlements, were only partly offset by a net CO_2 sink in the biomass. In the base year 1990, a net source of about 710 Gg CO_2-eq. from the same land-use changes was registered.

[146] Stock change, positive: C sink; negative: C source

[147] Emissions, positive: GHG source; negative: GHG sink

[148] N_2O emissions from organic soils under grassland are reported as part of the agricultural sector

11.3.1.1.2 Biomass

Forest management and afforestation

Information on methods used for calculating carbon stocks, and carbon-stock changes, in above-ground and below-ground biomass is presented in the following chapters:

- Forest Land remaining Forest Land, cf. Chapter 6.4.2.2.1.
- Land converted to Forest Land cf. Chapter 6.4.2.2.2.

Additional methodological descriptions are presented in the following chapters:

- Derivation of individual-tree biomass, cf. Chapter 6.4.2.2.3.
- Conversion to above-ground individual-tree biomass, cf. Chapter 6.4.2.2.4.
- Conversion to below-ground biomass, cf. Chapter 6.4.2.2.5.
- Conversion of individual-tree biomass to carbon, cf. Chapter 6.4.2.2.6
- Procedures for scaling up to relevant states in 1987, 2002 and 2008, cf. Chapter 7.2.4.1.7.
- With regard to up-scaling procedures for stock changes, using the "stock-difference method," cf. Chapter 6.4.2.2.8.
- Interpolation of time periods, to obtain annual-change estimates, cf. Chapter 6.4.2.2.9.

Deforestation:

With regard to deforested areas, an individual-tree calculation was carried out on the basis of the BWI (NFI) 1987, BWI 2002 and BWI 2012 inventories. The data of the 2008 Inventory Study were not taken into account, due to the small size of that survey's sample of trees on deforestation areas. For the period between the BWI 1987 and BWI 2002 inventories, only trees in the old German Länder were considered, since the BWI 1987 inventory was carried out only there. The wood-stocks data for the old German Länder were applied to the new German Länder. The emission factor for the decreasing above-ground and below-ground biomass for the period 1990 through 2001 is -28.93 Mg C ha^{-1} a^{-1}. For the period as of 2002, an individual-tree calculation, spanning the BWI 2002 and BWI 2012 inventories, was carried out for Germany as a whole. The emission factor for the decreasing above-ground and below-ground biomass for the period 2002 through 2013 is -54.66 Mg C ha^{-1} a^{-1}. The stocks of subsequent final land-use classes were deducted – and thus taken into account. The carbon stocks released upon deforestation are counted, completely, as emissions in the same year.

Cropland management:

Information on methods used for calculating carbon stocks, and carbon-stock changes, in above-ground and below-ground biomass is presented in Chapter 6.5.2.1, divided into the following categories:

- Permanent crops (perennial crops) – cf. Chapter 6.5.2.1.1 and Chapter 19.4.3.1. The following permanent-crops categories are considered: fruit trees, Christmas-tree plantations, wine grapes, short-rotation plantations, tree nurseries.
- For annual crops that are taken into account in connection with land-use changes, cf. Chapter 6.5.2.1.2. The biomass stocks are calculated from annual cultivation and yield statistics, in a manner consistent with the method used in Chapter 5 (agriculture) to calculate N inputs from crop residues.
- For aggregation of the biomass figures, cf. Chapter 6.5.2.1.3.

Grazing land management:

Information on methods used for calculating carbon stocks, and carbon-stock changes, in above-ground and below-ground biomass is presented in Chapter 6.6.2.2.1.

11.3.1.1.3 Dead wood

Forest management and afforestation:

Information on methods used for calculating carbon stocks and carbon-stock changes in dead wood is presented in the following chapters:

- With regard to Forest Land remaining Forest Land, cf. Chapter 6.4.2.3.1.
- For Land converted to Forest Land, cf. Chapter 6.4.2.3.2.

Deforestation:

The C stocks in dead wood were calculated with data of the BWI 2002, the 2008 Inventory Study (IS08) and the BWI 2012. In the BWI 2002, terrestrial sampling was limited to dead wood with a diameter > 20 cm at its thicker end, for fallen dead wood, or with a DBH > 20 cm, for standing dead wood (BMVEL 2001). For other sampling, the boundary used conformed to the provisions for climate reporting, i.e. was > 10 cm.

For the dead-wood diameter class > 20 cm, the change in dead-wood C stocks was calculated with the data of the BWI 2002 and 2012, for the period 2002 through 2012. For the diameter class 10 cm through 20 cm, the change was calculated for the period 2008 through 2012, with the data of the IS08 and the BWI 2012. For the same diameter class in the period 2002 through 2008, the ratio of the two diameter classes' changes in dead-wood C stocks for the period 2008 through 2012 was used as a basis. The mean value for the change in dead-wood C stocks in the period 2002 through 2012 was used as the change in such stocks for the period 1990 through 2002. Table 355 presents the changes in dead-wood C stocks for the different relevant periods and diameter classes. For the year 2013, the emission factor for the period 2008 through 2012 has been extrapolated. In each case of deforestation, the carbon stocks in dead wood, for the relevant year, were taken into account immediately as C emissions.

Table 355: Emission factors (EF) for dead wood for the periods 1990-2001, 2002-2007 and 2008-2012

Mg C ha^{-1} a^{-1}	1990 - 2001	2002 - 2007	2008 - 2012
EF dead wood, total	-1.884	-1.817	-1.986
EF dead wood, diameter class > 20cm	-1.298	-1.298	-1.298
EF dead wood, diameter class 10 through 20cm	-0.586	-0.519	-0.687

Cropland management and grazing land management:

Dead wood does not occur in connection with cropland management and grazing land management. Dead wood and tree cuttings are removed from areas with permanent crops. Such measures have already been taken into account in the biomass calculation.

11.3.1.1.4 Litter

Forest management and afforestation:

Information on methods used for calculating carbon stocks and carbon-stock changes in litter is presented in the following chapters:

- For Forest land remaining Forest Land, cf. Chapter 6.4.2.4.1.
- For Land converted to Forest Land, cf. Chapter 6.4.2.4.2.

Additional methodological descriptions are presented in the following chapters:

- Derivation of litter carbon stocks in 1990 (BZE I) and 2006 (BZE II/BioSoil), cf. Chapter 6.4.2.4.3.
- Derivation of carbon-stock changes in litter in the period from 1990 (BZE I) to 2006 (BZE II/Biosoil), cf. Chapter 6.4.2.4.4.

Deforestation:

Calculations relative to the litter ground cover were carried out with the status data of the BZE I and BZE II forest soil inventories. According to the relevant calculations, the average carbon stocks in litter amounted to 19.05 Mg ha^{-1} in 1990 (BZE I) and to 18.83 Mg ha^{-1} in 2006 (BZE II / BioSoil). For the years 1991 through 2005, the stocks were derived by interpolating the status data for the years 1990 and 2006. For the period as of 2007, the stocks were obtained via extrapolation. In each case of deforestation, the carbon stocks in litter, for the relevant year, were taken into account immediately as C emissions.

Cropland management and grazing land management:

Litter does not occur in connection with cropland management and grazing land management, and it has already been taken into account in the relevant biomass pool.

11.3.1.1.5 Mineral soils

Forest management:

- Information on methods used for calculating carbon stocks and carbon-stock changes in mineral soils of the "Forest Land remaining Forest Land" area is provided in Chapter 6.4.2.5.1.

Additional methodological descriptions are presented in the following chapters:

- Derivation of carbon stocks and carbon-stock changes, cf. Chapter 6.4.2.5.3.
- Results of derivation of carbon stocks and carbon-stock changes, cf. Chapter 6.4.2.5.4.

Afforestation and deforestation:

- For each land-use-change category, the carbon-stock changes in mineral soils are calculated as the difference between the carbon stocks of the final land-use category and the carbon stocks of the original land-use category. Pursuant to the IPCC Guidance (IPCC 1996b, 2003, 2006), the total changes are linearly distributed over a period of 20 years (cf. Chapter 6.1.2.1). For afforested and deforested areas, the carbon-stock changes in mineral soils were calculated in keeping with the procedures in Table 356 and Chapter 19.4.2. For each relevant year, the forest-soil carbon stocks were calculated via linear interpolation of the C stocks given in the forest-soil surveys.

Table 356: **Implied** emission factors (IEF) **[Mg C ha^{-1} a^{-1}]** for mineral soils in the categories afforestation and deforestation (negative = emission, positive = removal)

[Mg C ha^{-1} a^{-1}]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
KP 3.3 Afforestation/Reforestation	-0.61723	-0.60737	-0.59751	-0.58765	-0.57778	-0.56792	-0.55806	-0.54820	-0.53834	-0.52847
KP 3.3 Deforestation	0.38178	0.37204	0.36229	0.35254	0.34279	0.33305	0.32330	0.31355	0.30381	0.29406
[Mg C ha^{-1} a^{-1}]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
KP 3.3 Afforestation/Reforestation	-0.51861	-0.51291	-0.50685	-0.50046	-0.49380	-0.48688	-0.47576	-0.46471	-0.45374	-0.44991
KP 3.3 Deforestation	0.28431	0.28356	0.28177	0.27910	0.27568	0.27163	0.26386	0.25588	0.24771	0.23450
[Mg C ha^{-1} a^{-1}]	**2010**	**2011**	**2012**	**2013**						
KP 3.3 Afforestation/Reforestation	-0.40758	-0.36867	-0.33285	-0.29023						
KP 3.3 Deforestation	0.20151	0.17154	0.14421	0.12320						

Cropland management:

The mineral soils category is subdivided by land use, soil type / soil-parent-rock groups and climate region (cf. Chapter 19.4.2.2). Information on methods used for calculating carbon stocks and carbon-stock changes in mineral soils is presented in Chapter 6.5.2.2 and Chapter 6.1.2.1.1.

For areas remaining as cropland, national measurements show no change in carbon stocks in mineral soils. The constancy of carbon stocks since the early 1990s is evidenced by the results obtained on 140 regional long-term-trial areas (HÖPER und SCHÄFER 2012; FORTMANN et al. 2012 and BAYERISCHE LANDESANSTALT FÜR LANDWIRTSCHAFT 2007). The observations agree with the data derived from agricultural statistics, for the period since 1990, on manure production and on carbon inputs into soils from crop residues and catch crops, and those data are consistent with the relevant data, presented in Chapter 5 (agricultural sector) on nitrogen inputs into agricultural soils. While carbon inputs from manure have been decreasing since 1990, those decreases are more than offset by increases in crop residues that have been resulting from increasing harvests, from changes in crop selections and from increases in catch-crop cultivation.

Grazing land management:

The "mineral soils" category is subdivided by land use, soil type / soil-parent-rock groups and climate region (cf. Chapter 19.4.2.2). Information on methods used for calculating carbon stocks and carbon-stock changes in mineral soils is provided in Chapter 6.6.2.3.

For areas remaining as grassland (in the strict sense), national measurements show no change in carbon stocks in mineral soils. The constancy of carbon stocks is substantiated by the results obtained on 42 long-term-trial areas in Germany (HÖPER und SCHÄFER 2012, FORTMANN et al. 2012 and BLU 2011). The pertinent long-term observations cover a period of 20 – 25 years. During that period, most of the areas studied exhibited no changes in the carbon stocks in mineral soils. Some soils showed slight reductions, while others exhibited slight increases that nearly exactly offset the decreases, both in terms of numbers and in absolute terms. There are no indications that any major changes in management of permanent grassland have occurred since 1990 that could affect carbon stocks in mineral soils.

11.3.1.1.6 Organic soils

Information on methods used for calculating carbon stocks and carbon-stock changes in organic soils is presented in the following chapters:

- Forest Land remaining Forest Land, cf. Chapter 6.4.2.6.1.
- Land converted to Forest Land cf. Chapter 6.4.2.6.2.

Deforestation:

- For land converted to forest land, the carbon-stock changes in organic soils were calculated in keeping with the procedures in Table 357 and Chapter 6.1.2.2. The area-weighted emission factor for deforestation in 2013 is -2.37 Mg C ha^{-1}. It is important to remember that these calculations do not yield the carbon-stock difference between forest land and the subsequent use; they yield the emissions for the new use, in keeping with drainage intensity. Organic soils under forest already emit -2.61 Mg C ha^{-1} a^{-1}.

Table 357: Emission factors for organic soils of deforestation categories of the year 2013 (negative = loss; positive = sink)

Land-use change	Emission factor [Mg C ha^{-1} a^{-1}]
Forest land converted to cropland	-8.10
Forest land converted to grassland	-6.85
Forest Land converted to woody gl.	-2.61
Forest land converted to wetlands	-2.37
Forest land converted to water	0.00
Forest land converted to settlements	-7.40
Forest land converted to other land	0.00

Cropland management and grazing land management:

Emission factors for organic soils were derived from spatially explicit data. This was done by differentiating the frequency distribution for depths to water table by uses, and by applying regressions betweens depths to water table and CO_2 emissions. For land-use changes, the emission factor for the new land-use category applies right away. Additional information is presented in the following chapters:

- Derivation of emission factors, cf. Chapter 6.1.2.2.
- Methods for cropland, cf. Chapter 6.5.2.2
- Methods for grassland (in the strict sense), cf. Chapter 6.6.2.4

11.3.1.1.7 Harvested wood products

As described in detail in Chapter 6.10, the emissions contribution made by harvested wood products in Germany, in terms of sources and removals into sinks for greenhouse gases, was determined with the *WoodCarbonMonitor* model, in keeping with the specifications of the *IPCC KP Supplement* (IPCC 2014).

First, the availability of activity data, i.e. data on the production of and foreign trade in harvested wood products, was reviewed (cf. Chapter 2.8.1.1, IPCC 2014), and the product fractions originating from the domestic harvest were calculated. Then, in a second step (cf. Chapter 2.8.1.2, IPCC 2014), the carbon contained in those products was allocated, using the procedure described in Chapter 6.10.2.1, to the forest activities listed in the Kyoto Protocol under Article 3, paragraphs 3 and 4. For Germany, the wood harvest can be fully assigned to the two activities *forest management* and *deforestation*. In keeping with the provisions of the *IPCC KP Supplements* (IPCC 2014), harvested wood products from deforestation are taken into account on the basis of instantaneous oxidation. As a result, the annual wood-harvest fractions from the activity forest management $f_{FM}(i)$ can be calculated from the inventory information available for Germany and from Equation 2.8.3 (IPCC 2014).

Further information, and details on the emission factors used and on the calculation carried out for Germany, in keeping with the provisions of the *IPCC KP Supplement* (IPCC 2014), are provided in Chapters 6.10.2.2 and 6.10.2.3.

11.3.1.1.8 Other greenhouse-gas emissions

Forests:

- Nitrous oxide emissions from nitrogen fertilisers (CRF Table 4(KP-II)1); cf. Chapter 6.4.2.7.1
- Drainage and rewetting of organic and mineral soils (CRF Table 4(KP-II)2); cf. Chapter 6.4.2.7.2
- Direct nitrous oxide emissions from nitrogen mineralization and immobilization (CRF Table 4(KP-II)3); cf. Chapter 6.4.2.7.3
- Indirect nitrous oxide emissions from cultivated soils (CRF Table 4(KP-II)3); cf. Chapter 6.4.2.7.4
- Forest fires (CRF Table 4(KP-II)4); cf. Chapter 6.4.2.7.5

Cropland management and grazing land management:

- Drainage and rewetting of organic and mineral soils (CRF Table 4(KP-II)2); cf. Chapters 6.1.2.2, 6.5.2.3, 6.6.2.4
- Direct nitrous oxide emissions from nitrogen mineralization and immobilization (CRF Table 4(KP-II)3); cf. Chapter 6.1.2.1.2
- Indirect nitrous oxide emissions from cultivated soils (CRF Table 4(KP-II)3); cf. Chapter 6.1.2.1.2

For purposes of Kyoto reporting, the direct and indirect nitrous oxide emissions are combined, and the pertinent joint emission factor is reported in CRF Table 4(KP-II)3. N_2O emissions from organic soils under cropland management and grazing land management are reported in the agricultural sector, in the sub-category cultivation of histosols.

11.3.1.2 Justification when omitting any carbon pool or of greenhouse-gas emissions / removals from activities under Article 3.3 and elected activities under Article 3.4

No fertilisation of forest areas, with mineral fertilisers, takes place in Germany. For this reason, fertilisation with mineral fertilisers is listed as NO (not occurring) in the CRF tables 4(KP-II)1.

Dead wood and litter do not occur in connection with cropland management and grassland management (NO; not occurring).

11.3.1.3 Information on whether or not indirect and natural greenhouse gases and removals have been factored out

No indirect or natural greenhouse-gas emissions or sinks were taken into account.

11.3.1.4 Changes in data and methods since the previous submission (recalculations)

Because the IPCC KP Supplements (IPCC 2014) and the IPCC 2006 Guidelines (IPCC 2006) have been implemented in this year's submission, a complete recalculation of the inventory, and of all category-specific time series for the first year (2013) of the second commitment period of the Kyoto Protocol, was carried out on the basis of these provisions.

In this year's submission, cropland management and grazing land management are being reported for the first time.

11.3.1.5 Estimation of uncertainties

The uncertainties for the Kyoto Protocol (KP), for Article 3.3 Afforestation/deforestation and 3.4 Forest management, cropland management and grazing land management, were determined in keeping with the provisions of the IPCC 2006 Guidelines (IPCC, 2006). The uncertainty statistics commonly given for a normal distribution include the 95 % confidence interval, ± half of the 95 % confidence interval or 1.96 x the standard error, in % of the mean. For asymmetric distributions – in the present context, usually consisting of data sets with a logarithmic normal distribution – the relevant deviations are described as upper and lower bounds, expressed as % values of the pertinent position scale. The propagation of uncertainties was calculated via a conservative estimation in which the distance between the extreme value of the sloping axis section and the position scale is defined as half of the 95 % confidence interval.

Table 358 shows the results of uncertainties calculation for all pools and sub-categories of the KP 3.3/3.4 inventory, with the exception of harvested wood products (cf. Chapter 10.3.1.5.3). The total uncertainty is ± 25.26 %.

Further information relative to uncertainties is provided as follows: for estimation of land-use-change areas, in Chapter 6.4.3.1; for above-ground and below-ground biomass and dead wood, in Chapter 11.3.1.5.1; for litter and mineral soils, in Chapter 11.3.1.5.2; and summarised for the LULUCF sector overall, in Chapter 19.4.4.

Table 358: Uncertainties for greenhouse-gas reporting under the Kyoto Protocol, Articles 3.3 and 3.4

A Category	Pool	B Gas	C Base year emissions [CO_2- eq.] Gg a^{-1}	Base year emissions; contribution in [CO_2- eq.] Gg a^{-1}	D Year 2013 emissions [CO_2- eq.] Gg a-1	Year 2013 emissions; contribution in [CO_2- eq.] Gg a^{-1}	E Activity data uncertainty (half the 95% confidence interval) %	F Emission factor uncertainty (half the 95% confidence interval) %	G Combined uncertainty (half the 95% confidence interval) %	H Combined uncertainty as % of total national emissions in year t %
KP 3.3 Afforestation/Reforestation	Mineral soil	CO_2	57.703	57.703	488.623	488.623	5.524	54.784	55.062	0.073
KP 3.3 Afforestation/Reforestation	Organic soil	CO_2	24.203	24.203	452.949	452.949	5.524	24.601	25.214	0.013
KP 3.3 Afforestation/Reforestation	Organic soil	CH_4	0.341	0.341	6.390	6.390	5.524	1,011.573	1,011.588	0.004
KP 3.3 Afforestation/Reforestation	Organic soil	N_2O	1.919	1.919	35.906	35.906	5.524	200.686	200.762	0.005
KP 3.3 Afforestation/Reforestation	Phytomass, above-ground	CO_2	399.382	399.382	-5,229.484	5,229.484	5.524	28.126	28.663	2.278
KP 3.3 Afforestation/Reforestation	Phytomass, below-ground	CO_2	192.074	192.074	-971.306	971.306	5.524	40.925	41.296	0.163
KP 3.3 Afforestation/Reforestation	Litter	CO_2	-48.813	48.813	-868.781	868.781	5.524	3.147	6.357	0.003
KP 3.3 Afforestation/Reforestation	Dead wood	CO_2	-3.533	3.533	-63.844	63.844	5.524	48.686	48.999	0.001
KP 3.3 Afforestation/Reforestation	SOM	N_2O	9.312	9.312	88.090	88.090	5.524	174.228	174.316	0.024
KP 3.3 Deforestation	Mineral soil	CO_2	-14.490	14.490	-101.377	101.377	8.282	305.189	305.301	0.097
KP 3.3 Deforestation	Organic soil	CO_2	17.315	17.315	397.597	397.597	8.282	46.620	47.350	0.036
KP 3.3 Deforestation	Organic soil	CH_4	1.149	1.149	23.604	23.604	8.282	217.958	218.116	0.003
KP 3.3 Deforestation	Organic soil	N_2O	2.059	2.059	48.215	48.215	8.282	124.763	125.038	0.004
KP 3.3 Deforestation	Phytomass, above-ground	CO_2	745.946	745.946	1,411.150	1,411.150	8.282	25.774	27.072	0.148
KP 3.3 Deforestation	Phytomass, below-ground	CO_2	69.779	69.779	182.857	182.857	8.282	40.572	41.409	0.006
KP 3.3 Deforestation	Litter	N_2O	869.641	869.641	721.558	721.558	8.282	3.147	8.860	0.004
KP 3.3 Deforestation	Dead wood	CO_2	86.250	86.250	76.563	76.563	8.282	56.762	57.363	0.002
KP 3.3 Deforestation	SOM	N_2O	0.000	0.000	3.779	3.779	8.282	174.932	175.128	0.000
KP 3.4 Forest Management	Mineral soil	CO_2	-16,227.747	16,227.747	-15,905.934	15,905.934	1.234	52.585	52.600	70.959
KP 3.4 Forest Management	Organic soil	CO_2	3,176.685	3,176.685	2,761.011	2,761.011	1.234	24.601	24.632	0, 469
KP 3.4 Forest Management	Organic soil	CH_4	44.812	44.812	38.948	38.948	1.234	1,011.573	1,011.573	0.157
KP 3.4 Forest Management	Organic soil	N_2O	251.819	251.819	218.868	218.868	1.234	200.686	200.690	0.196
KP 3.4 Forest Management	Phytomass, above-ground	CO_2	-53,424.025	53,424.025	-35,926.646	35,926.646	1.234	63.014	63.026	519.750
KP 3.4 Forest Management	Phytomass, below-ground	CO_2	-5,084.759	5,084.759	-5,310.659	5,310.659	1.234	49.725	49.740	7.074
KP 3.4 Forest Management	Litter	CO_2	509.969	509.969	498.161	498.161	1.234	294.000	294.003	2.175
KP 3.4 Forest Management	Dead wood	CO_2	-1,502.015	1,502.015	2,069.747	2,069.747	1.234	106.869	106.876	4.960
KP 3.4 Forest Management	Forest fires / wildfires	CH_4	6.770	6.770	1.092	1.092	15.000	35.000	38.079	0.000

A Category	Pool	B Gas	C Base year emissions [CO_2- eq.] Gg a^{-1}	Base year emissions; contribution in [CO_2- eq.] Gg a^{-1}	D Year 2013 emissions [CO_2- eq.] Gg a-1	Year 2013 emissions; contribution in [CO_2- eq.] Gg a^{-1}	E Activity data uncertainty (half the 95% confidence interval) %	F Emission factor uncertainty (half the 95% confidence interval) %	G Combined uncertainty (half the 95% confidence interval) %	H Combined uncertainty as % of total national emissions in year t %
KP 3.4 Forest Management	Forest fires / wildfires	N_2O	4.464	4.464	0.720	0.720	15.000	35.000	38.079	0.000
KP 3.4 Forest Management	SOM	N_2O	0.000	0.000	0.000	0.000	1.234	178.720	178.724	0.000
KP 3.4 to Cropland Management	Mineral soil	CO_2	2648.97	2648.97	3053.12	3053.12	4.78	30.63	31.00	0.908
KP 3.4 to Cropland Management	Organic soil	CO_2	2316.80	2316.80	2404.33	2404.33	4.78	45.65	45.90	1.234
KP 3.4 to Cropland Management	Organic soil	CH_4	50.70	50.70	52.62	52.62	4.78	233.93	233.98	0.015
KP 3.4 to Cropland Management	Phytomass, above-ground	CO_2	121.81	121.81	-390.35	390.35	4.78	37.03	37.34	0.022
KP 3.4 to Cropland Management	Phytomass, below-ground	CO_2	250.26	250.26	278.88	278.88	4.78	37.98	38.28	0.012
KP 3.4 Cropland Management	Mineral soil	CO_2	0.00	0.00	0.00	0.00	1.05	50.50	50.52	0.00
KP 3.4 Cropland Management	Organic soil	CO_2	9418.78	9418.78	7989.89	7989.89	1.05	45.65	45.66	13.491
KP 3.4 Cropland Management	Organic soil	CH_4	206.13	206.13	174.86	174.86	1.05	233.93	233.93	0.170
KP 3.4 Cropland Management	Phytomass, above-ground	CO_2	0.00	0.00	0.00	0.00	1.05	9.07	9.13	0.00
KP 3.4 Cropland Management	Phytomass, below-ground	CO_2	0.00	0.00	0.00	0.00	1.05	27.06	27.08	0.00
KP 3.4 total Cropland Management	**SOM**	**N_2O**	**328.42**	**328.42**	**378.16**	**378.16**	**1.04**	**178.43**	**178.43**	**0.462**
KP 3.4 to Grazing Land Management	Mineral soil	CO_2	-2007.54	2007.54	-1587.75	-1587.75	7.95	30.63	31.64	0.256
KP 3.4 to Grazing Land Management	Organic soil	CO_2	- 4311.34	4311.34	-3197.79	3197.79	7.95	55.35	55.92	3.242
KP 3.4 to Grazing Land Management	Organic soil	CH_4	91.36	91.36	67.77	67.77	7.95	258.59	258.71	0.031
KP 3.4 to Grazing Land Management	Phytomass, above-ground	CO_2	-440.00	440.000	-212.08	212.08	7.95	37.03	37.87	0.007
KP 3.4 to Grazing Land Management	Phytomass, below-ground	CO_2	38.46	38.46	50.38	50.38	7.95	37.98	38.81	0.00
KP 3.4 Grazing Land Management	Mineral soil	CO_2	0.00	0.00	0.00	0.00	1.63	77.87	77.89	0.00
KP 3.4 Grazing Land Management	Organic soil	CO_2	-4876.83	4876.83	-5561.55	5561.55	1.63	55.35	55.38	9.616
KP 3.4 Grazing Land Management	Organic soil	CH_4	15.16	15.16	17.29	17.29	1.63	258.59	258.60	0.002
KP 3.4 Grazing Land Management	Phytomass, above-ground	CO_2	0.00	0.00	0.00	0.00	1.63	6.35	6.56	0.000

A Category	Pool	B Gas	C Base year emissions [CO_2- eq.] Gg a^{-1}	Base year emissions; contribution in [CO_2- eq.] Gg a^{-1}	D Year 2013 emissions [CO_2- eq.] Gg a-1	Year 2013 emissions; contribution in [CO_2- eq.] Gg a^{-1}	E Activity data uncertainty (half the 95% confidence interval) %	F Emission factor uncertainty (half the 95% confidence interval) %	G Combined uncertainty (half the 95% confidence interval) %	H Combined uncertainty as % of total national emissions in year t %
KP 3.4 Grazing Land Management	Phytomass, below-ground	CO_2	0.00	0.00	0.00	0.00	1.63	71.66	71.68	0.000
KP 3.4 total Grazing Land Management	**SOM**	**N_2O**	**0.00**	**0.00**	**0.00**	**0.00**	**1.62**	**179.79**	**179.80**	**0.00**
Total			**109,899.55**	**109,899.55**	**99,320.68**	**99,320.68**			**Root ∑ H**	**25.26**
									∑ H	**638.07**

11.3.1.5.1 *Estimation of uncertainties of emission factors for biomass and dead wood, for KP Art. 3.3 and KP Art. 3.4 Forest management*

Table 359 shows the uncertainties that result for the calculation of C stock changes in living biomass, as carried out in keeping with the information provided in Chapter 6.4.3.2. The following should be noted in this regard:

- It was not possible to derive emission factors for KP Afforestation/Reforestation and KP Deforestation for the new German Länder for the period 1993 – 2002, since the Datenspeicher Wald forest database does not contain the data necessary for such derivation. Consequently, the emission factors for the old German Länder have been used for that period.
- In the 2008 Inventory Study, no afforestation areas were surveyed, and those survey data for deforested points lack reliability. For this reason, the emission factors and applicable errors for the period 2002 through 2012 have also been derived from the data of the BWI 2002 and BWI 2012.

Table 359: Total error for estimation of C-stock changes in biomass for the inventory periods of the National Forest Inventory, 1987–2002, 2002–2008 and 2008–2012; RMSE% – root mean square error percent

RMSE%	1987-2002 Old German Länder	1993-2002 New German Länder	2002-2008 Germany as a whole	2008-2012 Germany as a whole
Afforestation (KP 3.3)	13.08	-	11.53	11.53
Deforestation (KP 3.3)	12.73	-	10.95	10.95
Forest Management (KP 3.4)	6.95	10.05	28.75	12.60

Table 360 shows the uncertainties that result, on the basis of the information provided in Chapter 6.4.3.2, for the calculation of C-stock changes in dead wood. The following should be noted in this regard:

- For deforestation, the applicable error for the period 1987 through 2002 was derived from the mean error for the period 2002 through 2012.
- For areas under forest management, the applicable dead-wood error for the period 1987 through 2002 was calculated from the mean error for the period 2002 through 2012.

Table 360: **Total error for estimation of C-stock changes in dead wood for the inventory periods of the National Forest Inventory, 1987–2002, 2002–2008 and 2008–2012; RMSE% – root mean square error percent**

RMSE%	1987-2002	2002-2008	2008-2012
Afforestation (KP 3.3)	24.84	24.84	24.84
Deforestation (KP 3.3)	28.96	24.88	44.46
Forest Management (KP 3.4)	46.67	27.11	54.52

The total-error calculation for purposes of reporting under the Kyoto Protocol is presented in Table 358 in Chapter 11.3.1.5.

11.3.1.5.2 *Estimation of uncertainties of emission factors for mineral soils and litter, for KP Art. 3.3 and KP Art. 3.4 Forest management*

The following uncertainties result for the emission factors for mineral soils and litter, as carried out in keeping with the information provided in Chapter 6.4.3.3 (cf. Table 361):

Table 361: Error budget for the emission factors for mineral soils and litter; se = standard deviation of the mean value; C 90, C 06 = laboratory error in carbon-stocks determination, BZE I and BZE II; FE = error in determination of the fine-earth fraction

LULUCF category	Pool	Emission factor					
		se [%]	C 90 [%]	C 06 [%]	FE [%]	Error total [%]	Uncertainty [%]
KP Forest Management	Litter	105.9	111.2	73.4		168.9	337.8
KP Forest Management	Mineral soil	9.0	14.1	13.6	12.2	26.7	53.4

11.3.1.5.3 Estimation of uncertainties for harvested wood products

Pursuant to information in the IPCC KP Supplement (IPCC 2014), the uncertainties for the activity data for harvested wood products amount to -25/+5%. For the emission factors, the default values listed in Table 2.8.2 of the IPCC KP Supplement are used. Those values include no uncertainties. Due to the lack of uncertainties, no error calculation can be carried out for harvested wood products.

11.3.1.6 Information on other methodological issues

In this chapter, the individual-pools results in the present submission are compared with those of other countries. As described in Chapter 6.4.4.3, the comparison of Germany with other countries is carried out only to provide a general classification, since the various countries differ in their choice of methods of approaches, and especially with regard to their definitions of "forest" and to their choices of activities under Article 3.4. Among the countries that are roughly comparable to Germany, only one – Denmark – has reported cropland management and grassland management to date. For this reason, no comparison with other countries is provided with regard to these voluntary activities.

A by-country comparison of afforestation-related carbon-stock changes in living above-ground biomass (Table 362) shows that Germany has the second-largest carbon sink. Only the Netherlands report a larger carbon sink. With regard to the pool of below-ground living biomass, Germany has the largest carbon-storage results from afforestation. In this category, it ranges slightly ahead of France, followed by the Netherlands, both of which report similar carbon-storage results. Denmark is the only country to have registered carbon losses in both above-ground and below-ground biomass. In the deforestation category, all countries report carbon losses. Germany can report the smallest carbon losses in the area of below-ground biomass, however. With regard to the pool of above-ground living biomass, only Austria has a smaller carbon source than Germany does. The largest carbon losses via deforestation, in both above-ground and below-ground biomass, are reported by the Czech Republic, followed by Denmark and Belgium. In the forest management category, Germany's carbon sinks in the area of above-ground biomass rank in the middle segment of the group ranking. By contrast, Germany has the smallest sink in the area of below-ground biomass. Denmark has the largest sink in this category.

In the litter category (Table 363), Germany's value for carbon storage related to afforestation ranks in the middle. The largest value – and, thus, the largest C sink – is found in Austria. In the deforestation category, Germany's carbon losses rank in the middle of the range for the group, while France reports the lowest losses. The highest losses from deforestation occurred in the Netherlands and in Poland. Forest management produces a slight carbon source only in Germany. Carbon-storage results in this category are seen in Switzerland, Denmark and the UK, while France and Poland report neither losses nor storage.

In the dead wood pool (Table 364), France, followed by Germany and Austria, report small carbon sinks in the afforestation category. Denmark, on the other hand, reports a small carbon source. In the deforestation category, Germany has small carbon losses. Most of the other countries have comparable carbon-source values. Only Switzerland reports higher carbon losses in this area. Austria is the only country to report having no carbon losses from deforestation. Switzerland also has the largest carbon source in the forest management category. Germany has a small carbon source in this area, a source comparable to the carbon losses of France and Poland. Only Denmark reports storage – on a slight level – from forest management.

In the mineral soils (Table 365) category, Germany is the only country with carbon losses as a result of afforestation. The largest carbon sinks in this area are in Belgium, the UK and Switzerland, while the other countries in the comparison have only medium-sized sinks or (in most cases) small sinks. On the other hand, Germany is the only country, apart from Denmark, with a carbon sink in the deforestation category. The smallest carbon losses are found in the Czech Republic, while the largest C losses, far and away, are seen in Poland, followed by Switzerland. In the category of forest management, Germany is again reporting the largest carbon sink. Along with the UK and Poland, it has registered growth in carbon sequestration, while other countries either have recorded no carbon-stock changes or are not reporting such changes.

Along with Germany, only Switzerland, Denmark, Poland, the UK and the Netherlands report with regard to organic soils (cf. Table 366). Germany has registered carbon losses in all three categories. The Netherlands have far and away the largest losses via afforestation. A carbon sink in this category is seen only in the UK. All comparable countries also show deforestation-related carbon losses in organic soils. In this area as well, the Netherlands, followed by Switzerland, have the largest losses. In the area of forest management, Germany, in comparison to the other reporting countries, has the largest carbon losses. The UK is the only country to again have a C sink in this category.

Table 362: Carbon-stock changes in living biomass (Germany, for 2013; other countries, for 2013)

Country[149]	**Afforestation / Reforestation [Mg C ha^{-1}]**		**Deforestation [Mg C ha^{-1}]**		**Forest Management [Mg C ha^{-1}]**	
	above-ground	**below-ground**	**above-ground**	**below-ground**	**above-ground**	**below-ground**
AUT	0.96	0.26	-0.73	-0.18	NA	NA
BEL	1.62	0.32	-3.17	-0.63	NA	NA
CHE	1.31	0.36	-4.15	-1.34	0.54	0.18
CZE	1.65	0.33	-2.61	-0.52	0.68	0.14
DNK	-0.13	-0.06	-3.56	-0.77	1.46	0.33
FRA	1.08	0.48	-1.91	-0.47	0.60	0.21
GBR	1.22	IE	-2.48	IE	1.24	IE
GER	**2.81**	**0.52**	**-1.42**	**-0.18**	**0.90**	**0.13**
NLD	3.40	0.45	-2.99	-0.49	NA	NA
POL	0.85	0.20	-2.75	-0.63	0.85	0.26

Source: UNFCCC 2014

[149] AUT = Austria, BEL = Belgium, CHE = Switzerland, CZE = Czech Republic, DNK = Denmark, FRA = France, GBR = UK, GER = Germany, NLD = the Netherlands, POL = Poland

Table 363: Carbon-stock changes in litter (Germany, for 2013; other countries, for 2012)

Country[149]	Afforestation / Reforestation [Mg C ha⁻¹]	Deforestation [Mg C ha⁻¹]	Forest Management [Mg C ha⁻¹]
AUT	1.01	-0.56	NA
BEL	NO	-0.28	NA
CHE	NO	-0.95	0.03
CZE	IE	IE,NA	IE,NO
DNK	0.02	-0.83	0.47
FRA	0.20	-0.23	0.00
GBR	0.07	-0.40	0.22
GER	**0.47**	**-0.73**	**-0.01**
NLD	NE	-1.53	NA
POL	NO	-1.07	0.00

Source: UNFCCC 2014

Table 364: Carbon-stock changes in dead wood (Germany, for 2013; other countries, for 2012)

Country[149]	Afforestation / Reforestation [Mg C ha⁻¹]	Deforestation [Mg C ha⁻¹]	Forest Management [Mg C ha⁻¹]
AUT	0.02	0.00	NA
BEL	NO	-0.07	NA
CHE	NO	-0.29	-0.19
CZE	NO	-0.07	NO
DNK	-0.03	-0.08	0.04
FRA	0.04	-0.07	-0.04
GBR	IE	IE	IE
GER	**0.03**	**-0.08**	**-0.05**
NLD	NE	-0.08	NA
POL	NO	-0.08	-0.04

Source: UNFCCC 2014

Table 365: Carbon-stock changes in mineral soils (Germany, for 2013; other countries, for 2012)

Country[149]	Afforestation / Reforestation [Mg C ha⁻¹]	Deforestation [Mg C ha⁻¹]	Forest Management [Mg C ha⁻¹]
AUT	0.60	-0.68	NA
BEL	1.21	-1.35	NA
CHE	0.90	-1.76	0.00
CZE	0.13	-0.05	NE,NO
DNK	0.15	0.09	NA,NR
FRA	0.21	-0.72	0.00
GBR	1.05	-0.69	0.22
GER	**-0.29**	**0.12**	**0.41**
NLD	0.18	0.00	NA
POL	0.09	-1.74	0.11

Source: UNFCCC 2014

Table 366: Carbon-stock changes in organic soils (Germany, for 2013; other countries, for 2012)

Country[149]	Afforestation / Reforestation [Mg C ha^{-1}]	Deforestation [Mg C ha^{-1}]	Forest Management [Mg C ha^{-1}]
AUT	NO	NO	NA
BEL	NO	NO	NA
CHE	-0.68	-5.21	-0.68
CZE	NO	NO	NO
DNK	-0.34	NA	-0.34
FRA	NO	NO	NO
GBR	2.49	IE	0.79
GER	**-2.61**	**-2.37**	**-2.61**
NLD	-428.86	-6.52	NA
POL	-0.68	NO	-0.68

Source: UNFCCC 2014

11.3.1.7 The year of the onset of an activity, if after 2013

In the current 2015 Submission, emissions are reported for the year 2013, the first year of the second commitment period. For this reason, there are no activities after the year 2013.

11.4 Article 3.3

11.4.1 Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2020 and are directly human-induced

As described in Chapter 6.3, the procedure for determining land-use changes from and to forest land identifies area changes as of 1970, while the methods used for purposes of reporting under the Kyoto Protocol take account only of changes since 1990. As of the 2014 Submission, submissions take account of the results of the third National Forest Inventory (BWI 2012), for which the reference year is 2012. Those results provide the database for the initial year of the second commitment period. All included activities in this context thus fall within the period 1 January 1990 to 31 December 2020.

While each land-use change from and to forest land is recorded primarily via the National Forest Inventory (Bundeswaldinventur; BWI), such changes are also recorded in additional data sets. The relevant sampling points form a grid that covers all of Germany. Via repeated surveying of the sample points, all changes can be mapped on a large scale. If a point is mapped as forest that was mapped as non-forest in the previous inventory, it represents a specific area of afforestation. The BWI differentiates between afforestation via planting / sowing and afforestation via natural rejuvenation. However, an area afforested via natural rejuvenation is classified as *afforested* only when the relevant stand has an average age of five years and crown cover of at least 50 % (cf. Chapter 6.2.1).

Agricultural land can change from (managed) cropland to unmanaged land and, via spontaneous establishment of trees (natural rejuvenation), into forest land. Pursuant to the IPCC KP Supplements, afforestation may be accounted only if it is "directly human-induced". "It is *good practice* to provide documentation that all afforestation and reforestation activities included (…) are directly human-induced. Relevant documentation includes forest management records or other documentation that demonstrates that a decision had been taken to replant or to allow forest regeneration by other means."[150] German law requires a "permit from the competent authority under the law of the Länder" (Art. 10 (1) Federal Forest Act (BWaldG)) for each afforestation. Pursuant to Para. 2, no permit is required only in those cases in which, for the area to be afforested, "afforestation has been mandated in a legally binding way, on the basis of other public legal provisions, or the requirements of regional planning and Land (state) planning are not affected". Germany is a densely populated, intensively managed country in which all areas nation-wide are subject to land-use plans. In addition, Germany has different planning levels, ranging from large-scale planning (e.g. regional planning) to specific small-scale planning (e.g. landscape plans, operational plans for forest management). Preparation of, and compliance with, plans is monitored by the relevant competent authorities in each case, including authorities of the Federal Government, of the Länder and of individual municipalities. Thus it may be assumed that all afforested areas fulfill the "directly human-induced" requirement, since the act of permission, as well as the act of mandating in a legally binding manner and the preparation and establishment of regional and landscape plans all presuppose active decisions by humans.

11.4.2 Information on how harvesting or forest disturbance that is followed by re-establishment of forests is distinguished from deforestation

Pursuant to Art. 11 (1) Federal Forests Act (BWaldG), "forests (…) (should) be properly and sustainably managed, in the framework of their defined purposes. Länder laws are to be enacted that set forth obligations for all forest owners whereby clear-cut or degraded forest areas

19. are to be reforested, or
20. replenished, in cases in which natural regrowth remains incomplete,

within a reasonable period of time, unless conversion to another type of use has been approved or is otherwise permitted."

In general, reforestation is called for on all forest areas that are to remain in use as forest land. That is a legal requirement, and it is the customary practice in the German forestry sector. Forest land that is temporarily unstocked thus continues to fall within the scope of required reporting on forest management pursuant to Art. 3.4 KP. The situation is different in cases in which forest land becomes unstocked and planning calls for subsequent use of the land to fall within the category "non-forest land". Such land is to be considered deforested land, with the relevant deforestation directly human-induced, regardless of whether the deforestation was caused by harvesting or by natural disturbances.

[150] Cf. IPCC **KP Supplements (2014)**, Section 2.5.2.

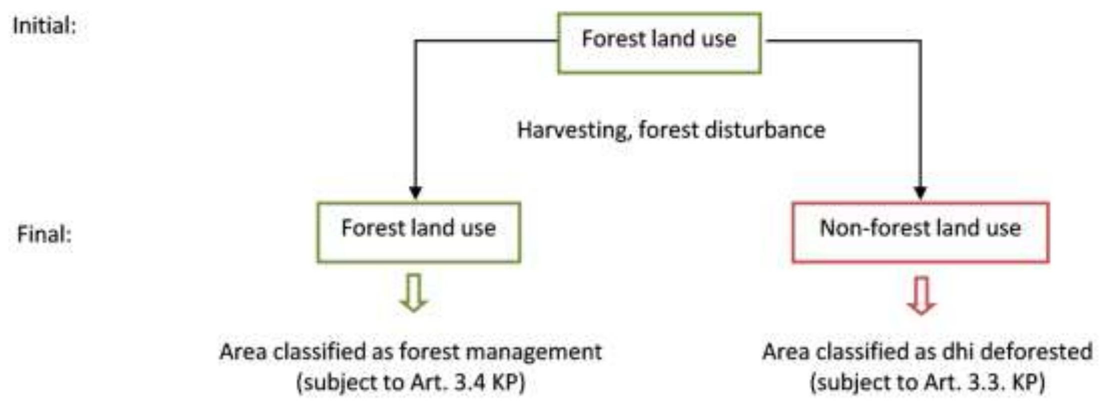

Figure 81: Scheme for differentiation between a) harvest or forest disturbance that is followed by reforestation, and b) deforestation

11.4.3 Information about the size and geographic location of forest areas that have lost forest cover but which are not yet classified as deforested

Forest management routinely generates small unstocked areas (bare areas) in forests. Pursuant to the data of the BWI 2012, such areas total about 41,742 ha and account for 0.36 % of the total forest area. As explained above in Chapter 11.4.2, such areas continue to fall within the national forest definition and continue to figure in calculations relative to carbon stocks and their changes.

11.5 Article 3.4

11.5.1 Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human-induced

11.5.1.1 Forest management

Since an integrated procedure is used for surveying forest lands, land-use changes and the carbon-stock changes caused by relevant activities, the statements made in Chapter 11.4.1 apply mutatis mutandis for the activity "forest management".

Pursuant to Art. 1 No. 1 Federal Forest Act (BWaldG), "forests are to be preserved, to be enlarged as necessary and to be properly and sustainably managed, in light of their economic value (utility function) and of their importance with regard to the environment, especially the long-term vitality of natural systems and cycles, and with regard to climate, water cycles, air quality, soil fertility, landscape beauty, agrarian structures and infrastructure and the population's needs for rest and recreation (protection and recreation functions)".

Forests are thus assigned three key basic functions, namely utility, conservation and recreation functions, in light of which they are to be preserved and properly and sustainably managed. In addition, Art. 11 (1) p. 1 BWaldG sets forth that "forests (…) (should) be properly and sustainably managed, in the framework of their defined purposes." While that formulation does not mean that forests "must" be managed, and thus it does not establish a general obligation, it is important to note that it does not use "may" phrasing, which would rule out any obligation.

The wording chosen thus clearly reveals a basic orientation – namely, that forests should be managed. An obligation to manage forest lands thus applies to all of Germany[151].

In the interest of protecting forests' three basic functions, forests, pursuant to Art. 1 No. 1 in conjunction with Art. 11 (1) p.1 BWaldG, should be protected and properly and sustainably managed. The aim of proper forest management as set forth by the Marrakesh Accords (MA) thus agrees with the requirements set forth by the Federal Forest Act (BWaldG). In both cases, management is oriented to the aim of ensuring that the forest can continue to fulfill its functions in perpetuity.

The Marrakesh Accords define forest management as "a system of practices". That indicates that management involves actions / measures. A forest area that is left untouched, and for which no measures are taken, is thus not a managed forest area. For a forest area to qualify as "unmanaged", however, no human activities may take place in it, i.e. no active human interventions may be permitted in it (equivalent to MCPFE conservation category 1.1). Forest areas meeting those criteria are "practically non-existent" in Germany (BMELV, 2009). In 2007, forest conservation areas in which permitted human interventions are restricted to a minimum, i.e. fully protected areas (MCPFE conservation category 1.2), accounted for 1.1% of Germany's total forest area, and were tending to be enlarged (BMELV, 2009). The primary focus with regard to such forest areas is on biotope and species conservation (for example, protected forests, natural forest reserves, core zones of national parks and biosphere reserves). Certain types of interventions are expressly permitted, however (for example, measures to control wildfires, hoofed game, diseases or insect calamities[152]). For protected forests, as for all protected areas, concepts are to be prepared that set forth / define / describe the object/focus of protection, the protection purpose, the necessary requirements and prohibitions for achieving the protection purpose and the necessary relevant care, management, development and restoration measures[153] (for example, in ordinances or guidelines on protected areas; cf. for example, Art. 23 (2) State Forest Act (LWaldG) of Mecklenburg – West Pomerania). In addition, some 23% of Germany's forest area consists of protected areas whose conservation purpose is actively assured via management measures (MCPFE conservation category 1.3); 56 % consist of forests whose primary purpose is to conserve landscapes and specific natural elements (MCPFE conservation category 2); and 34 % have the primary purpose of providing protective functions (MCPFE conservation category 3). In MCPFE conservation categories 1.3 through 3, management is to be aligned with the relevant conservation purpose. Such categories thus fulfill the criteria for forest management. Human activities for protecting conservation areas are also certainly allowed in MCPFE category 1.2. Pursuant to the 2006 IPCC Guidelines, such areas thus fulfill forest-management criteria in accordance with Art. 3.4 KP: "For example forested national parks (…) where these parks are managed to fulfil relevant ecological (including biodiversity) and social functions, and are subject to forest management activities such as fire suppression, a country may choose to include these forested national parks as lands subject to forest management."[154] It should be noted that the aforementioned area shares in the different forest-conservation categories

[151] Häusler and Scherer-Lorenzen (2002) speak of an obligation, for all forest owners, "to carry out sustainable, proper management"; the citation appears in: Nachhaltige Forstwirtschaft in Deutschland im Spiegel des ganzheitlichen Ansatzes der Biodiversitätskonvention. BfN – Skripten 62, p. 5 and 15.

[152] In addition, environmentally compatible measures to develop forests for recreational purposes and for nature-compatible research are permitted.

[153] Cf. for example, Art. 22 (1) Federal Nature Conservation Act (BnatSchG).

[154] IPCC KP Supplements (2014) Chapter 2.7.2 and IPCC 2006 Guidelines, Chapter 2, Volume 4

cannot simply be summed, since they overlap to some extent; in some cases, the same forest area will have been repeatedly included (BMELV, 2009).

Large parts of Germany's forest lands are subject to planning. According to estimates of the BMEL, forest-management plans (economic plans, operational plans or reports) are in place for about ¾ of the country's forested area (BMELV, 2009). In addition to such operational plans, in many cases forest landscape plans (forest framework plans) are also prepared for forests, in the framework of landscape planning[155]. The aim of forest framework planning is to "safeguard the forest functions necessary for the development of ecological and economic conditions pursuant to Art. 1 No. 1 (BWaldG)". That accords precisely with the aim prescribed by IPCC GPG (IPCC 2003) with respect to forest management. To that end, measures may be, or must be, prescribed (cf. for example, Art. 6 (3) No. 4 p. 2 BWaldG old version; Art. 6 (1) No. 2 Bavarian Forest Act (BayWaldG); Art. 9 (4) State Forest Act (LWaldG) of Mecklenburg – West Pomerania; Art. 6 p. 2 Forest and Landscape Act of the State of Lower Saxony (NWaldLG); Art. 7 (1) State Forest Act for the State of North Rhine – Westphalia (LFoG NRW); Art. 6 (2) Forest Act of the State of Saxony-Anhalt (WaldG Sachsen-Anhalt)[156]). In some cases, requirements explicitly call for such planning to serve as a guideline for management, inter alia (cf. Art. 8 (3) LFoG NRW).

All in all, it must thus be considered confirmed that all forests in Germany are managed in accordance with forest-management criteria as set forth by the Marrakesh Accords and by the IPCC KP Supplements (2014).

A compilation of excerpts from state forest acts, relative to requirements for forest management and for forest framework planning, is provided by STEUK (2010). A pertinent summary is presented in Table 367.

[155] Until 2005, the Federal Forest Act (BWaldG) required the preparation of forest framework plans. Because the Länder differ widely in their planning structures, those provisions were eliminated, however. Cf. BMELV (2009) Waldbericht der Bundesregierung (Forest Report of the Federal Government), p. 28.

[156] For definition of measures in operational plans, cf. Art. 5 (6) p. 3 State Forest Act (LWaldG) of Schleswig-Holstein.

Table 367: Overview of obligations relative to forest management, preparation of plans and use of forest framework plans, as set forth by the forest acts of the Länder

State (Land)	Forest-management obligations			Obligations to prepare plans (economic plans, operational plans, operational reports or other specialised forest-management plans)			Obligations to prepare forest framework plans
	State forest	Municipal forest	Private forest	State forest	Municipal forest	Private forest	
Baden-Württemberg	X	X	X	X	X	(X)	(X)
Bavaria	X	X	X	X	[X]		(X)
Berlin	X	X	X				X
Brandenburg							X
Bremen	X	X	X				
Hamburg	X	X	X				X
Hesse	X	X	X	X	X	[X]	
Mecklenburg – West Pomerania	X	X	X				X
Lower Saxony	X	X	X	[X]	[X]		X
North Rhine – Westphalia	X	X	X		X		X
Rhineland-Palatinate	X	X	X	[X]	[X]	[X]	X
Saarland	X	X	X	X	X	(X)	X
Saxony	X	X	X	X	X		(X)
Saxony-Anhalt	X	X	X	X	X		X
Schleswig-Holstein				[X]	[X]		
Thuringia	X	X	X	X	X	[X]	X

Legend:

X Binding requirement (includes "should" requirements)

[X] Requirement is binding only under certain conditions (for example, conditions pertaining to minimum size)

(X) Optional guideline / not binding (a "can" requirement)

10.5.1.2 Cropland management and grazing land management

All areas under cropland management and grazing land management are subject to periodic cultivation measures (carried out once or several times per year), and thus the pertinent emissions and removals are anthropogenic.

11.5.2 Information relative to cropland management and grazing land management for the base year

11.5.2.1 Cropland management

The emissions from cropland management in 1990 are dominated by CO_2 from organic soils. Carbon losses from mineral soils, as a result of conversions of grassland (in the strict sense) to cropland, are also significant (Table 364a). The emission pattern is very similar to that seen in 2013 (Table 342a).

Table 368: Carbon-stock and greenhouse-gas emissions as a result of cropland management, in the base year 1990

Sub-categories	C-stock changes in biomass, 1990[157] [Gg C]	C-stock changes in mineral soils, 1990[93] [Gg C]	CO_2 from organic soils, 1990[93] [Gg C]	CH_4 from organic soils, 1990[158] [Gg CH_4]	Direct and indirect N_2O from decomposition of organic material in mineral soils, 1990[94] [Gg N_2O]	Total, 1990[94/159] [Gg CO_2-eq.]
Cropland remaining cropland	0	0	-2,568.76	8.24	0	9624.79
Land-use change from grassland (in the strict sense) (GM to CM)	-24.97	-702.93	-443.90	1.42	1.07	4650.96
Land-use change from woody grassland	-55.60	-19.29	-5.46	0.02	0.03	304.06
Land-use change from terrestrial wetlands	-3.56	-3.91	0.00	0.00	0.00	27.39
Land-use change from waters	3.88	0.00	0.00	0.00	0.00	-14.23
Land-use change from settlements	-21.95	3.15	-182.50	0.59	0.00	752.85
Land-use change from other land	0.73	0.53	0.00	0.00	0.00	-4.62
Total for LUC to cropland	**-101.47**	**-722.45**	**-631.86**	**2.03**	**1.1**	**5716.40**
Total for LUC from cropland	**0.00**	**0.00**	**0.00**	**0**	**0**	**0.00**
Total	**-101.47**	**-722.45**	**-3200.62**	**10.27**	**1.1**	**15341.19**

Emissions and removals from land-use changes from cropland to other land-use categories are taken into account under Art. 3.3 (afforestation), Art. 3.4 (grazing land management) or, in keeping with the IPCC KP Supplements (IPCC 2014), Chapter 2.9.2, are accounted as zero. N_2O emissions from organic soils under cropland are reported in the agricultural sector, in the sub-category cultivation of histosols.

11.5.2.2 Grazing land management

The emissions from grazing land management in 1990 are dominated by CO_2 from organic soils. The carbon sink in mineral soils, in the land-use changes category, only slightly offsets the emissions (Table 364b). The emission pattern is very similar to that seen in 2013 (Table 342b).

157 Stock change, positive: C sink; negative: C source

158 GHG emissions, positive: GHG source; negative: GHG source

159 N_2O emissions from organic soils under cropland management are reported as part of the agricultural sector

Table 369: Carbon-stock and greenhouse-gas emissions as a result of grazing land management, for the year 1990

Sub-categories	C-stock changes in biomass, 1990[160] [Gg C]	C-stock changes in mineral soils, 1990[96] [Gg C]	CO_2 from organic soils, 1990[96] [Gg C]	CH_4 from organic soils, 1990[161] [Gg CH_4]	Direct and indirect N_2O from decomposition of organic material in mineral soils, 1990[97] [Gg N_2O]	Total, 1990[97/162] [Gg CO_2-eq.]
Grassland (in the strict sense) remaining as Grassland (i.t.s.s.)	0	0	-4,876.83	15.16	0	18260.70
Land-use change from cropland (CM to GM)	18.16	445.72	-785.94	2.44	0	1241.92
Land-use change from woody grassland	-114.23	9.40	-125.55	0.39	0	854.48
Land-use change from terrestrial wetlands	-2.19	0.40	-8.53	0.03	0	38.47
Land-use change from waters	14.77	0.00	-117.45	0.37	0	385.62
Land-use change from settlements	-30.09	78.70	-138.35	0.43	0	339.81
Land-use change from other land	4.07	13.28	0.00	0.00	0	-63.62
Total for LUC to grassland (in the strict sense)	**-109.50**	**547.51**	**-1175.82**	**3.65**	**0**	**2796.57**
Total for LUC from grassland (in the strict sense)	**0**	**0**	**0**	**0**	**0**	**0**
Total	**-109.50**	**547.51**	**-6052.65**	**18.81**	**0.00**	**21057.27**

Emissions and removals from land-use changes from grassland (in the strict sense) to other land-use categories are taken into account under Art. 3.3 (afforestation), Art. 3.4 (grazing land management) or, in keeping with the IPCC KP Supplements (IPCC 2014), Chapter 2.10.2, are accounted as zero. N_2O emissions from organic soils under grassland (in the strict sense) are reported in the agricultural sector, in the sub-category cultivation of histosols.

11.5.3 Information relating to Forest Management

As explained above in Chapter 11.5.1, the law requires German forests to be managed properly and sustainably. National provisions on forest management are set forth in the Federal Forest Act (BWaldG). In addition, the Länder have their own Land (state) forest acts in place that further detail the provisions of the Federal Forest Act. A comparison of Germany's national provisions with the relevant international definition shows broad agreement.

International definition pursuant to the Marrakesh Accords[163]*:*

"'Forest management' is a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner."

National definitions pursuant to state forest acts (Landeswaldgesetze - LWaldG):

[160] Stock change, positive: C sink; negative: C source

[161] GHG emissions, positive: GHG source; negative: GHG source

[162] N_2O emissions from organic soils under grassland are reported as part of the agricultural sector

[163] Paragraph 1 lit. f of Annex A of Decision 16/CMP.1

Pursuant to Art. 1 No. 1 Federal Forest Act (BWaldG), the purpose of the Act is, in particular, "to conserve forest for the sake of its economic value (utility function) and for the sake of its (…) (conservation and recreation function), to increase it, if necessary, and to assure its proper management for the long term". Pursuant to Art. 11 (1) p. 1 BWaldG, forests are to be "managed properly and sustainably, in the framework of their defined purposes." In keeping with the Federal Government's restricted legislative competence in this regard, the Federal Government simply provides a framework that the Länder implement and detail with regard to specific applications (cf. Art. 5 and Art. 11 (1) p. 2 BWaldG). As a result, the Länder define what is to be understood by "proper and sustainable forest management". A compilation of relevant sections of Länder forest acts is provided by STEUK (2010).

The forest-management requirements pursuant to Länder forest acts are comparable to those set forth by international forest legislation. The requirement that forests are to be managed sustainably, with a view to fulfilling ecological (including biological diversity), economic and social functions[164], is found in all Länder forest acts. In Germany, ecological, economic and social functions are often referred to as "conservation, utility and recreation" functions[165] (cf. Table 370). Where the ecological, economic and social functions that are to be served by management are not referred to explicitly as such in Länder laws, the laws add the phrase "within the framework of its [their] defined purposes"[166]. Forests are thus to be managed sustainably, within the framework of their defined purposes. This orientation is found in Art. 1 BWaldG (purpose of the act), which appears verbatim in every Land forest act. In addition, Art. 1 No. 1 BWaldG sets forth that forests are to be protected especially "in light of their economic value (utility function) and their (…) (conservation and recreation functions)". The aim of protecting economic, ecological and social functions is thus found in all such laws. Furthermore, both the Federal Forest Act and the forest acts of the Länder warrant the sustainability of forest management.

Table 370: Comparison of forest functions pursuant to the Federal Forest Act and the IPCC

Forest functions pursuant to BWaldG	Forest functions pursuant to MA
Utility function	Economic functions
Conservation function	Ecological functions
Recreation function	Social functions

11.5.4 Forest Management Reference Levels (FMRL)

11.5.4.1 Methodical description

Pursuant to resolution 2 / CMP.793, for the second commitment period of the Kyoto Protocol, anthropogenic greenhouse-gas emissions from sources and sinks that result from forest management under Article 3.4, are to be accounted against the Forest Management Reference Levels (FMRL). In each case, the FMRL contains a value that projects the average annual net emissions from forest management, in the second commitment period, from historic data and political decisions.

[164] Cf. Art. 4 No. 1 BayWaldG; Art. 1a LFoG NRW; a similar meaning also is seen in Art. 6 (1) LWaldG RLP; and a similar meaning is seen in Art. 18 (1) in conjunction with Art. 19 (1) p. 2 ThürWaldG.

[165] Cf. Art. 1 No. 1 BWaldG; Art.13 LWaldG BW; Art. 11 (2) No. 1 LWaldG B; Art. 4 (2) LWaldG Bbg; Art.5 (1) BremWaldG, Art. 6 (1) HeFoG; Art. 6 (1) No. 1 LWaldG MV; Art. 11 (1) NWaldLG; Art. 5 (1) LWaldG SH.

[166] Cf. Art. 6 (1) LWaldG Ha; Art. 11 (1) LWaldG SL; Art. 17 SächsWaldG; Art. 4 (1) WaldG LSA; Art. 18 (1) ThürWaldG.

For Germany, an FMRL of –22.41 $MtCO_2$-eq per year has been reported. The documents submitted in 2011 relative to the FMRL, and the pertinent review report, are provided on the UNFCCC website http://unfccc.int/bodies/awg-kp/items/5896.php. Those documents include a description of the methods used to obtain the FMRL.

11.5.4.2 Technical correction

The IPCC KP Supplements require a technical correction of the FMRL if methodological changes result in calculation of the time series, if new historical data become available or if pools are included in current reporting that have not been taken into account in the FMRL. The reference level developed to date does not contain all pools and other emissions that, pursuant to the current rules for GHG reporting, are reported relative to KP 3.4 and thus are part of the pertinent accounting. For this reason, Germany has to carry out a technical correction of the FMRL. Due to a lack of predictive models – models that are currently being developed, however – Germany cannot carry out this technical correction in the current 2015 Submission. It will provide it in subsequent submissions, however.

11.6 Other information

11.6.1 Key-category analysis for Article 3.3 activities and any elected activities under Article 3.4

In connection with analysis for the UNFCCC inventory, key-category analysis was also carried out for activities pursuant to Article 3.3 and for selected activities pursuant to 3.4. The results are presented in tabular form in Chapter 1.5.2 of this report. The procedures, bases and methods used are described in detail in Chapter 17.1.4.

11.7 Information relative to Article 6 (JI & CDM projects / management of ERU)

Pursuant to Paragraph 5 (1) Sentence 1 of the Project Mechanisms Act (Projekt-Mechanismen-Gesetz; ProMechG), no projects in the area of LULUCF may be approved in Germany that are to take place in Germany.

12 INFORMATION RELATIVE TO ACCOUNTING FOR KYOTO UNITS

13 INFORMATION ON CHANGES IN THE NATIONAL SYSTEM

The focus of work in the period covered by the report was on preparing the national system, and on adjusting it institutionally, for the requirements imposed by the 2nd commitment period of the Kyoto Protocol and by the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. No other changes were made in 2014 in the institutionalisation of the National System.

14 INFORMATION ON CHANGES IN THE NATIONAL REGISTRIES

15 INFORMATION REGARDING MINIMISATION OF NEGATIVE IMPACTS PURSUANT TO ARTICLE 3 (14)

16 OTHER INFORMATION

This chapter is currently not required.

17 ANNEX 1: KEY CATEGORIES WITHIN THE GERMAN GREENHOUSE-GAS INVENTORY

Pursuant to the *2006 IPCC Guidelines*, the parties to the UN Framework Convention on Climate Change and to the Kyoto Protocol are required to calculate and publish emissions data annually.

These emissions inventories must be readily comprehensible (transparency); must be calculated in a consistent manner in the time series since 1990 (consistency); must be evaluated uniformly at the international level via application of the prescribed calculation methods (comparability); must contain all the relevant emission sources and sinks in the reporting country (completeness); must be evaluated with regard to error; and must undergo ongoing internal and external quality management (accuracy).

To facilitate concentrating the many and detailed activities and resources required for this purpose on the inventory's principal categories, the IPCC has introduced the term "key category." Key categories are categories which are highlighted in the national inventory system because their emissions have a significant influence on total emissions of direct greenhouse gases, either in terms of absolute emissions, or as a contribution to the emissions trend over time, or in both ways.

Chapter 4 of the 2006 IPCC Guidelines describes the methods to be applied for identifying key categories. These methods include inventory analysis for one year (Approach 1, Level Assessment), time-series analysis of inventory data (Approach 1, Trend Assessment), detailed analysis of inventory data with error evaluation (Approach 2, Trend Assessment with consideration of uncertainties) and assessment of qualitative criteria (pursuant to Chapter 4.3.3 2006 IPCC GL)

Approach 1 analyses must always be carried out using two procedures. In a first procedure, only emissions from sources are evaluated, and storage in sinks is not considered. In a second procedure, emissions storage in sinks is then included (without any consideration of whether it is positive or negative). As would be expected, the two results differ. Pursuant to the 2006 IPCC GL, both results must be taken into account in identification of key categories.

For identified key categories, the Parties are then required to use highly detailed calculation methods (Tier 2 or higher; the relevant methods are also specified in the 2006 IPCC GL). Should direct use of such methods prove impossible, for whatever reason (e.g. data are not available for the required input variables, etc.), Parties are required to prove that the methods applied nationally achieve at least a comparable degree of accuracy in the calculation result. Such proof, as well as the key-category analysis performed overall, must be outlined in the national inventory report to be prepared annually.

17.1 Description of the method for identifying key categories

The results of key-category analysis via the two Approach 1 procedures (Level and Trend), the Approach 2 procedure and assessment in terms of qualitative criteria are outlined below. In this context, we call attention to the description of the underlying methods in the *2006 IPCC GL*. The annual emissions inventories were divided, with regard to their CO_2-equivalent emissions, into a total of 151 individual activities.

17.1.1 Approach 1 procedures

Level analysis has the purpose of identifying those categories that are responsible for 95 % of total national emissions (as CO_2-equivalent emissions), in the Kyoto Protocol's base year and in the current year; those categories are then defined as key categories (●). Calculations were performed using formula 4.1 from the 2006 IPCC Guidelines.

With the category structuring used for such analysis, Approach 1 level analysis identified a total of 35 key categories for the current report (cf. Table 6, Chapter 1.5).

Trend analysis identifies as key categories (●) those categories which have made an especially significant contribution to changes in total GHG emissions in the most recent year, in terms of the development of their contribution since the base year. In this respect, it is irrelevant whether such changes have led to a reduction or an increase in total emissions. Calculations were performed using formula 4.2 from the 2006 IPCC Guidelines.

With the category structuring used for such analysis, Approach 1 Trend analysis identified a total of 39 key categories (cf. Table 6, Chapter 1.5).

17.1.2 Approach 2 procedure

Key-category analysis using the Approach 2 procedure is based on the results of current uncertainties determination in accordance with Approach 1. In the present case, the results have provided extensive confirmation of the results of the Approach 1 key-category analyses. Six additional categories also have to be considered, however (cf. Table 8, Chapter 1.5.1).

17.1.3 Assessment with qualitative criteria

Germany assesses key categories with help of qualitative criteria. Chapter 4.3.3 of the 2006 IPCC Guidelines provides recommendations relative to the criteria to be applied. The criteria allow assessment on the basis of use of emissions-reduction equipment, of expected disproportionate emissions increases, of a high level of uncertainty or of unexpectedly lower or higher emissions in a given category. The criteria may be used as a basis for defining additional categories as key categories.

In the category adipic acid production (2.B.3), a redundant waste-gas-treatment system was installed. In light of that installation, the category has been classified as a key category, on the basis of qualitative criteria. 2.B.3 is already a key category, however, in terms of Approach 1 Level and Trend assessment. SF_6 emissions from soundproof windows are reported in 2.G.2. Even though such a trend cannot yet be recognized, it is clear that SF_6 emissions must be expected to increase sharply in coming years as disposal of old windows increases. For that reason – i.e. on the basis of qualitative criteria – the category has already been identified as a key category. That classification leads to no change, however, since 2.G is already a key category, according to Approach 1 Level and Trend, for SF_6. Qualitative assessment on the basis of large uncertainties is not required, since Germany carries out Approach 2 key-category analysis for the entire inventory every three years. No unexpectedly low or high emissions have been seen in the inventory.

Use of qualitative criteria has not identified any additional key categories in Germany.

Germany uses all recommended procedures for identifying and evaluating categories. The IPCC Guidelines mandate that 95% of emissions from sources / removals in sinks be classified in key categories. The key categories that Germany has identified comprise emission-causing activities that account for about 98 % of the total inventory. This high percentage results from Germany's practice of identifying key categories by combining the results of all analysis procedures and evaluations.

17.1.4 Key-category analysis for Kyoto reporting

The following CRF Table NIR.3 summarises information relative to key-category analysis for Kyoto reporting. Additional information is presented in Chapter 1.5.2.

Table 371: KP CRF Table NIR.3: Summary Overview for Key Categories for Land Use, Land-Use Change and Forestry Activities under the Kyoto Protocol

Key Categories of Emissions and Removals	**Gas**	**Criteria used for Key Category Identification**			Comments (3)
		Associated category in UNFCCC inventory(1) is key (indicate which category)	**Category contribution is greater than the smallest category considered key in the UNFCCC inventory (1), (4) (including LULUCF)**	**Other(2)**	
Specify key categories according to the national level of disaggregation used(1)					
Afforestation and Reforestation	CO_2	Conversion to forest land	Yes	High expected growth.	The value is very close to the value in the smallest category considered key in the UNFCCC inventory. The value has increased about tenfold since 1990.
Forest Management	CO_2	Forest Land remaining Forest Land	Yes	None	No Comment

(1) See section 5.4 of the IPCC good practice guidance for LULUCF.

(2) This should include qualitative consideration as per section 5.4.3 of the IPCC good practice guidance for LULUCF or any other criteria.

(3) Describe the criteria identifying the category as key.

(4) If the emissions or removals of the category exceed the emissions of the smallest category identified as key in the UNFCCC inventory (including LULUCF), Parties should indicate YES. If not, Parties should indicate NO.

18 ANNEX 2: DETAILED DISCUSSION OF THE METHODOLOGY AND DATA FOR CALCULATING CO_2 EMISSIONS FROM COMBUSTION OF FUELS

18.1 The German Energy Balance

In the Federal Republic of Germany, energy statistics are published by numerous agencies, and these statistics can differ in terms of their presentation, scope and aggregation. The Energy Balances of the Federal Republic of Germany, which are prepared under commission to the German Federal Ministry for Economic Affairs and Energy (BMWi), are the central data foundation for determining/preparing energy-related emissions, scenarios and forecasts of the impacts of energy-policy and environmental-policy measures. On an annual basis, the associations in the German energy sector, working in co-operation with economic research institutes, and in the framework of the Working Group on Energy Balances (AGEB), combine the relevant data to form a complete picture. They then make the data available to the public in the form of Energy Balances.

The complete Energy Balances for the years since 1990 are available in the Internet at:

http://www.ag-energiebilanzen.de/index.php?article_id=7&clang=0

The AGEB's website presents a foreword for the Energy Balances, in German and English, that describes the structure of the Energy Balance.

The members of the Working Group on Energy Balances (AGEB) include (as of: October 2013):

- German Association of Energy and Water Industries (BDEW), Berlin,
- Deutscher Braunkohlen-Industrie-Verein e.V. (DEBRIV) (Federal German association of lignite-producing companies and their affiliated organisations), Cologne,
- Deutsches Institut für Wirtschaftsforschung (DIW) (German Institute for Economic Research), Berlin,
- Institute of Energy Economics at the University of Cologne (EWI), Cologne,
- EEFA GmbH, Münster
- Gesamtverband des deutschen Steinkohlenbergbaus (GVSt) (Association of the German hard-coal-mining industry), Herne,
- Association of the German Petroleum Industry (MWV), Berlin,
- Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI) (Rhine-Westphalian institute for economic research), Essen.
- German Coal Importer Association (Verein der Kohlenimporteure e.V.), Hamburg
- Centre for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW), Stuttgart

The work of the Working Group on Energy Balances (AGEB) is also supported by the Energieeffizienzverband für Wärme, Kälte und KWK e. V. (AGFW; Association for energy efficiency in heating, cooling and CHP systems) and the Association of Industrial Energy and Power Producers (VIK). Since the 1994 balance year, overall responsibility for preparation of Energy Balances has lain with the German Institute of Economic Research (DIW; Berlin); since 2002, the DIW has carried out relevant work in co-operation with EEFA (Energy Environment Forecast Analysis GmbH) and with Mr. Rossbach (formerly with the Association of the German Petroleum Industry (MWV), who serves as a consultant for the section on petroleum. Overall, taking due regard for the available data, the Energy Balances provide a comprehensive picture of energy production and use quantities/structures in the German economy.

Official statistics are the most important source. The surveys of the Federal Statistical Office that were used are listed in Table 372. The final Energy Balance continues to include data of the following associations: German Association of Energy and Water Industries (BDEW), German Atomic Forum (DAtF), Gesamtverband Steinkohle association of the German hard-coal-mining industry (GVSt), DEBRIV Federal German association of lignite-producing companies and their affiliated organisations and Association of the German Petroleum Industry (MWV). In addition, for the period until 2011 figures for on wood consumption in the residential sector were obtained from GfK-Rheinbraun data that are reported via DEBRIV, in February/March of the relevant subsequent year + 1. The figures for wood consumption by the residential sector in 2012 are based on data collected in a survey of RWI. No figures are being entered for the Commercial and Institutional sector pending a pertinent decision of the Working Group on Energy Balances (AGEB).

For the final Energy Balance, data of the Working Group on Renewable Energy Statistics (Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat), relative to "renewable energy sources", are used; those data are provided in the publication "Erneuerbare Energien in Zahlen" ("facts and figures on renewable energies"). Provisional data on renewable energy sources are discussed with AGEE-Stat and the BDEW. They enter into the estimated Balance and, thus, into the evaluation tables.

In a number of categories, furthermore, experts personally provide relevant data – in categories, for example, such as non-energy-related consumption by the chemical industry.

18.2 Structure of the Energy Balances

The Energy Balances, which are structured in matrix form, provide an overview of the interconnections within the energy sector. As a result, they not only provide information about consumption of energy resources in the various source categories, they also show the relevant flows of such resources, from production to use in the various production, transformation and consumption areas. The ***production balance*** shows:

- domestic production
- imports
- removals from stocks
- exports
- maritime bunkering
- additions to stocks

of energy resources, and it summarises them under ***primary energy consumption***. The primary Energy Balance provides the basis for calculations under the IPCC reference procedure (PROGNOS, 2000). The ***usage balance*** provides a key basis for preparation of emissions inventories. The usage balance can also be used for determination of primary energy consumption. It comprises:

- the transformation balance
- flaring and line losses
- non-energy-related consumption, and
- final energy consumption.

Differences between the production and usage balances are compensated for in the position "Statistical differences".

The ***transformation balance***, part of the usage balance, shows what energy resources are transformed, as well as what other resources they are transformed into. The transformation production shows the results of such transformation. Energy transformation can involve either substance modification – such as transformation of crude oil (transformation input) into petroleum products (transformation production) – or physical transformation – such as combustion of hard coal (transformation input) – in power stations, for production of electrical energy (transformation production). The energy consumption in the transformation sector shows how much energy was needed for operation of transformation systems (the transformation sector's own consumption). The transformation balance is broken down by facility type; a total of 12 different types of facilities are considered.

Non-energy-related consumption, as a component of the consumption balance, is shown as a total, without allocation to facility types or branches of industry. It describes which energy resources are used as raw materials (e.g. in the chemicals industry, transformation of energy resources into plastics).

Finally, the consumption balance indicates the final consumption sectors in which energy is transformed into the useful energy ultimately needed (such as power, light, room and process heating) (***final energy consumption***). This includes industry, sub-divided into 14 sectors, transport, households and commercial use, trade, services and other consumers (including agriculture).

The energy flow in the Energy Balances is depicted for 30 energy resources. These energy resources can be allocated to the following main groups:

- hard coal,
- lignite,
- petroleum (including LPG and refinery gas),
- gases (coke-oven and blast furnace gas, natural gas and firedamp, and excluding landfill gas and the gases in the previous category),
- renewable energy resources (including waste fuels),
- other energy sources / fuels (non-renewable waste, waste heat)
- electrical power and other energy resources.

Energy Balances have been drawn up for the years 1990 to 1994, both separately for the old and new Länder and for Germany as a whole. With the conversion of the official statistics to the classification of industrial sectors (*FEDERAL STATISTICAL OFFICE*, 2002c), since 1995 only Energy Balances for Germany as a whole (in the territorial delimitation of 3 October 1990) have been submitted. Via the "Renewable energies" satellite balance, renewable energies are further broken down as of 1996 (AGEB 2003).

As of the year 2000, the energy-resource structure in the area of renewable energies / waste was changed: hydroelectric and windpower systems, and photovoltaic systems, were combined, and waste/biomass was divided into renewable and non-renewable fractions. Since 2004, non-recyclable waste and waste heat are also listed under final-energy consumption within the Energy Balance.

In the Energy Balance, fuels / energy resources are listed in *natural units*, including tonnes (t) for solid and liquid fuels, cubic metres (m^3) for gases, kilowatt hours (kWh) for electrical power, and joules (J) for waste, renewable energy sources, nuclear power and district heating. In order to render the data comparable and suitable for addition, all values are converted into joules (J) using calorific value tables and conversion factors. Unlike gas statistics or international Energy Balances, the Energy Balance lists even gases in terms of calorific value.

To date, Energy Balances through 2012 have been published. To meet the need for currentness in emissions reporting, the Working Group on Energy Balances (AGEB) provides the Federal Environment Agency with a complete provisional Energy Balance, for purposes of inventory preparation.

18.3 Methodological issues: Energy-related activity rates

Essentially, the inventories for air pollutants and greenhouse gases prepared by the Federal Environment Agency are based on the Energy Balances for Germany prepared by the Working Group on Energy Balances (AGEB). The data required for emissions calculation can be read directly from Energy Balance lines 11, 12, 15, 16, 40, 60, 65 and 68. For biomass fuels, EB line 14, depending or the fuel in question, also has to be used in calculation.

In a few cases, the special requirements pertaining to emissions calculation, and the need to assure the completeness of data, necessitate a departure from the above-described system, and additional data have to be added:

- The emissions-relevant fuel inputs for lignite drying have to be calculated out of EB line 10. A precise description of source category 1.A.1.c is provided in Chapter 3.2.8.2.
- Natural gas inputs in compressors, for the years 1995-2002, can be read directly from the Energy Balance (EB line 33). For the years 1990-1994, and for the period as of 2003, the values have to be calculated outside of the Energy Balance. The method is described in Chapter 3.2.10.5.2 (source category 1.A.3.e).
- For systematic reasons, and for reasons having to do with a focus on energy production, the Energy Balance does not list incinerated waste quantities completely for all relevant years. In this area as well, therefore, the lacking data have to be added from waste statistics. Relevant explanations are provided in Chapter 3.2.6.2 (1.A.1.a) and in Chapter 3.2.9.7.2 (1.A.2.g Other).
- Firewood use in the source categories commercial and institutional is not listed in the Energy Balance and has to be added. A description of source category 1.A.4 is provided in Chapter 3.2.11.2.

In the Energy Balance, inputs of reducing agents, in pig-iron production, are listed in part as energy-related consumption, in EB line 54, and in part as transformation inputs, in EB line 17 (top-gas equivalent). Use of the related blast-furnace gas for energy production is listed in the relevant Energy Balance lines, 11, 12, 15, 33 and 54. To prevent double counting, the reducing-agent inputs from blast furnaces, as listed in EB line 54, and the relevant top-gas equivalent, are not reported.

18.4 Uncertainties, time-series consistency and quality assurance in the Energy Balance

As a result of increasing energy-market liberalisation, and in conjunction with the formation of a European single market, the condition of the statistical energy database has worsened in recent years of change (ZIESING et al, 2003). While the Act on Energy Statistics (which entered into force in 2003) improved the relevant basic data foundations, relatively speaking, the dynamic development of the energy sector has again created a need for amendment of that Act.

The data structures of the Energy Balance are adjusted on an ongoing basis, in order to enhance data availability to the best possible extent.

These changes are made at relatively large intervals and are documented by the Working Group on Energy Balances (AGEB) in each case:

- Explanations relative to revision of the Energy Balances 2003 – 2006:
- Remarks regarding changes in the Energy Balances 2003 through 2007
- Revision of the Energy Balances 2003 through 2009
- Methodological changes in the 2012 Energy Balance

18.4.1 Quality reportof the Working Group on Energy Balances (AGEB) regarding preparation of Energy Balances for the Federal Republic of Germany

In 2012, the Working Group on Energy Balances (AGEB) began submitting annual joint quality reports, to the Federal Environment Agency (UBA), that document its quality-assurance measures in preparation of Energy Balances.

The following section presents the content of the current reports, in their original wording (different typeface).

18.4.1.1.1 Background

In the framework of greenhouse-gas reporting, the National Co-ordinating Committee for the National System of Emissions Inventories has established minimum requirements pertaining to quality control and quality assurance (QC/QA). Those requirements are to be fulfilled on all levels of inventory preparation. One of the most important data sets for determination of greenhouse-gas emissions consists of the Energy Balances for the Federal Republic of Germany, which the Working Group on Energy Balances (AGEB) has been commissioned to prepare. The German Institute for Economic Research (DIW, Berling) and the EEFA research institute also work on such Energy Balances, as sub-contractors to the AGEB. All persons working on Energy Balances are required to comply with minimum requirements pertaining to QC/QA, in areas such as transparency, consistency, comparability, completeness and accuracy.

To document its data sources and quality-assurance measures in preparation of Energy Balances, the Working Group on Energy Balances (AGEB) herewith submits its current quality report to the Federal Environment Agency (UBA). It focuses especially on the 2012 Energy Balance.

18.4.1.1.2 Work-sharing in preparation of Energy Balances

The DIW Berlin is responsible for preparing Energy Balances and evaluation tables for the following energy areas:

- Natural gas, petroleum gas
- Renewable energies (hydro, wind and photovoltaics; biomass and renewable waste; other renewable energy sources),
- Non-renewable waste, waste heat,
- Electricity,
- Nuclear energy and
- District heat.

Also in the framework of its Energy Balance work, the DIW Berlin coordinates the quarterly estimates of primary energy consumption for the Federal Republic of Germany, and it prepares estimates for the energy area "Other".

In addition, DIW Berlin awards a service contract to Mr. Ulrich Rossbach, who prepares the petroleum section of the Energy Balances. Mr Rossbach is responsible for preparing Energy Balances for the following energy areas:

- Crude oil, and
- Petroleum products (gasoline; naphtha; jet fuels; diesel fuel; light heating oil; heavy heating oil; petroleum coke; LP gas; refinery gas; other petroleum products).

The tasks of the EEFA research institute include preparing complete Energy Balances (including evaluation tables) for the following fuels:

- Hard coal, hard-coal coke, hard-coal briquettes and other hard-coal products,
- Lignite (raw), lignite briquettes, other lignite products and hard lignite, and the gases
- Coking-plant gas and city gas, top gas and converter gas, and pit gas.

In the framework of its work on the Energy Balances, the EEFA institute also coordinates deliveries and reporting of energy-statistics data in the context of European and international obligations (IEA/EUROSTAT Annual Joint Questionnaires).

Since Energy Balance year 2009, estimate balances have been prepared in the framework of work for the evaluation tables. They incorporate data from Statistik-Nr. 066 (Erhebung über die Elektrizitäts- und Wärmeerzeugung der Stromerzeugungsanlagen der allgemeinen Versorgung; Survey of electricity and heat generation of public-sector electricity generation systems) of the Federal Statistical Office (StBA), association data of the German Association of Energy and Water Industries (BDEW) and data of the Working Group on Renewable Energy Statistics (Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat) relative to "Other renewable energy sources". The estimates are coordinated especially with the BDEW and the AGEE-Stat.

At that early stage in Energy-Balance preparation, important official data sources, such as surveys relative to energy consumption of industrial sectors, are normally not yet available. The pertinent data gaps are closed with the help of estimates. It is clear that an estimated Energy Balance cannot fulfill the strict requirements pertaining to data quality that the corresponding final Energy Balance meets, a work published with a time lag of about one year.

18.4.1.1.3 Quality of the data sources used

For preparation of the Energy Balances for the Federal Republic of Germany, the DIW Berlin makes use of the following data of the Federal Statistical Office:

- Survey (No. 060) of energy use of mining, quarrying and manufacturing companies,
- Survey (No. 062) of geothermal energy,
- Survey (No. 067) of electricity generation systems in the mining and manufacturing sectors,
- Survey (No. 066) of electricity and heat generation of public-supply electricity generation systems,
- Survey (No. 64) of heat generation, demand, use and supply,
- Survey (No. 070) of network operators relative to electricity feed-in,
- Survey (No. 073) of production, use and supply of sewage gas,
- Survey (No. 082 P) of supply, import and export of natural gas and petroleum gas, and of revenue of producers,
- Survey (No. 082) of production, supply, import and export of gas, and of revenue of gas utilities and gas sellers.

In addition, data on biofuels are obtained from the Official Mineral Oil Statistics of the Federal Office of Economics and Export Control (BAFA).

The data of the Federal Statistical Office (StBA) and of the Federal Office of Economics and Export Control (BAFA) are subject to official quality requirements. The quality reports of the Federal Statistical Office are available in the Internet, at its Web site:

https://www.destatis.de/DE/Publikationen/Qualitaetsberichte/Energie/EnergieWasserversorgung.html.

In addition to available official data, the DIW Berlin also uses the following association data:

- Data on gross electricity generation in the Federal Republic of Germany (BDEW)
- Data on flaring losses (Wirtschaftsverband Erdöl- und Erdgasgewinnung German oil and gas industry association (WEG))
- Data on electricity generation in nuclear power stations (Deutsches Atomforum e.V.)

and data of the Working Group on Renewable Energy Statistics (Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat).

At regular intervals, the Federal Ministry for Economic Affairs and Energy (BMWi) commissions methodologically reliable studies that serve as a supplementary source of information on, and that support comparisons regarding, energy consumption of the residential and commercial / institutional sectors. In keeping with a recommendation of the BMWi's working group on methods (Arbeitskreis Methodik), the RWI/forsa study is being used as a data resource relative to wood consumption in the residential sector as of the 2010 Energy Balance.[167]

All scientific work at the DIW Berlin is required to conform to ethical principles for research and consultation. Such principles are based on the "Proposals for ensuring good scientific practice" ("Vorschläge zur Sicherung guter wissenschaftlicher Praxis") of the DFG's "Commission on "Self-regulation in the science sector" ("Selbstkontrolle in der Wissenschaft"), on the recommendations and rules for good scientific practice applied by the Leibniz Association and on the code of ethics of the Verein für Socialpolitik economists association.

In preparation of the petroleum sections of the Energy Balance for the Federal Republic of Germany, Mr Ulrich Rossbach uses the following official data:

- Official Mineral Oil Statistics for the Federal Republic of Germany (AMS), published by the Federal Office of Economics and Export Control (BAFA), Eschborn
- Survey (No. 060) of energy use of mining, quarrying and manufacturing companies,
- Survey (No. 067) of electricity generation systems in the mining and manufacturing sectors,
- Survey (No. 066) of electricity and heat generation of public-supply electricity generation systems,
- Survey (No. 064) of heat generation, demand, use and supply,
- Survey (No. 075) of production, demand, use and supply of LP gas,
- Finances and Taxes, Energy Tax, Fachserie 14, Reihe 9.3, StBA).

In addition to the available official data, the following data are also used:

- Statistics on petroleum production and consumption (MWV-Jahresbericht (annual reports) / MWV-Mineralöl-Zahlen (petroleum statistics), various years; Mineralölwirtschaftsverband e.V. Association of the German Petroleum Industry, Berlin)
- Company statistics, and diverse additional data items, on petroleum production and consumption (MWV, Berlin and MWV member companies; direct surveys of consumers and of associations)

[167] The possibility of using the surveys relative to the area of wood consumption in the commercial and institutional sector is currently being reviewed.

- Data on petroleum and natural gas production (annual report of the Wirtschaftsverband Erdöl- und Erdgasgewinnung (W.E.G.) German oil and gas industry association)
- Annual report, various years, German Liquid Petroleum Gas Association (Deutscher Verband Flüssiggas e.V. – DVFG), Berlin
- Statistics, various years, Association of German Transport Companies (Verband Deutscher Verkehrsunternehmen – VDV), Cologne
- Various studies on fuel consumption of machines in the "non-road" sector, Institute for Energy and Environmental Research (ifeu-Institut GmbH), Heidelberg

In preparing Energy Balances, the EEFA institute draws on a range of sources, in their order of importance, including official statistics, surveys and statistics of energy-sector associations and data from survey studies of research institutes. To close unavoidable data gaps, it relies on its own experts' assessments. The main official data sources used include the following:

- Survey (No. 060) of energy use of mining, quarrying and manufacturing companies,
- Monthly reports on coal imports,
- Survey (No. 067) of electricity generation systems of mining, quarrying and manufacturing companies,
- Survey (No. 066) of electricity and heat generation of electricity generation systems serving the public grid,
- Survey (No. 64) of heat generation, demand, use and supply.

In addition, in carrying out calculations for the Energy Balance, the EEFA institute uses numerous statistics provided by the Statistik der Kohlenwirtschaft coal-sector-statistics association. The Statistik der Kohlenwirtschaft association's key members include the Association of the German hard-coal mining industry (GVSt) and the DEBRIV Federal German association of lignite-producing companies and their affiliated organisations. Examples of statistics that enter into calculations relative to the hard coal sector include

- Statistics on domestic sales, broken down by types of hard coal and consumer groups, and
- Statistics on production, use in transformation sectors and changes in stocks (form 4a).

With regard to lignite, the following data are used:

- Data on extraction, production of lignite products, producers' own consumption and sales (form 5), and information from production reports,
- Data on domestic sales / use, broken down by Länder and consumer groups, and
- Data from other unpublished statistics.

The coal-statistics data available in Germany have a semi-official status, and they are very precise and reliable. For more than 60 years, the Statistik der Kohlenwirtschaft coal-sector-statistics association has served as a liaison between coal-sector companies and official producers of statistics (cf. in the Internet: http://www.kohlenstatistik.de/files/50jahre.pdf).

Official statistics in this area are based on surveys carried out by the Statistik der Kohlenwirtschaft association. Additional data on the coal sector, available to the general public, are provided in the annual publications "Der Kohlenbergbau in der Energiewirtschaft der Bundesrepublik Deutschland" ("Coal mining as a part of the energy sector of the Federal Republic of Germany") and "Zahlen zur Kohlenwirtschaft" ("Coal-industry statistics" (which no longer appear in printed form), and on the Web site http://www.kohlenstatistik.de. The superior transparency of these data sources (in some cases, highly specific data items are provided) attests to their reliability and accuracy. The Act on Energy Statistics

(Energiestatistikgesetz) has no separate paragraph relative to surveys on the domestic coal sector; its refers instead explicitly to the functioning system of coal statistics.

For preparation of Energy Balances, the important aspects of these data sources, in addition to their quality, include their multi-year availability and their standardised, consistent presentations of time series. Such aspects play a critically important role in ensuring that the procedures and methods used for preparation of Energy Balances generate data that can be consistently integrated, without structural discontinuities, in the basic scheme for the Balances. Both the official sources and – especially – the coal-sector statistics have long histories. In some areas, they provide consistent time series that reach far into the past. Where breaks in time series cannot be avoided, as a result of reviews or changes in statistical foundations (for example in the Act on Energy Statistics), such breaks are well-documented in the sources used for preparation of Energy Balances. This ensures that methods are always properly adjusted.

Yet another supplementary information source consists of studies that, for selected reference years, collect primary statistical data on energy consumption of the residential and commercial / institutional sectors. Such studies document the quality of their up-scaling results. It should also be noted that the Federal Ministry of Economics and Technology (BMWi) commissions research institutes to carry out such surveys. As a result, once the final report for such a survey has been accepted, the survey acquires a semi-official status that guarantees that it meets certain quality standards.

18.4.1.1.4 Transparency of methods and procedures

The Act on Energy Statistics (Energiestatistikgesetz – (EnStatG) entered into force on 1 January 2003. That act consolidates official energy statistics, from different legal frameworks, and adapts them to users' current information requirements. Since the act's entry into force, the Federal Statistical Office has also collected and provided data for the areas heat market, combined heat / power generation (CHP) and renewable energy sources. As a result of the restructuring, the Federal Statistical Office, in addition to providing data on electricity and heat generation from combined heat / power generation (CHP), also provides data on all fuel inputs for CHP, for both the general public supply and industry (broken down by energy sources).

Such changes in the available statistics have made it necessary to adjust the methods used for the Energy Balances – especially for their descriptions of industrial final energy consumption. As a consequence of the described expansion in the data supply, separate data on fuel inputs as of 2003 for industrial electricity generation – i.e. for electricity-only generation – are now available.

The Federal Statistical Office does not collect data on breakdowns of fuel inputs by "electricity" and "heat" in industrial and public-supply combined heat / power generation (CHP) systems; such statistics are collected by the Working Group on Energy Balances (AGEB) and estimated by institutes it commissions. The "Finnish" method used for such purposes is based on Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004. That method is exactly defined, mathematically, and it is explained in the forewords to the Energy Balances.

With regard to quality assurance, the Finnish method makes calculations relative to power/heat production for the public supply and for industry logical and transparent. The necessary pertinent framework assumptions, such as the reference efficiencies of non-CHP generation as provided in the documentation for the Energy Balances, are clearly stated in the process. In sum, although Energy Balance preparation is a process that makes use of frequently complex transformational methods, its results can still be highly transparent and unambiguous. As a result, all Energy Balance entry fields can always be traced back to their primary statistical foundations.

Primary data provided by official or association sources – regardless of its quality – can seldom simply be "plugged into" the Energy Balance without undergoing the statistical processing normally used to prepare the Energy Balances. Description of relevant complex energy flows, using matrices that conform to the formal parameters and methodological specifications for the Energy Balances, and on the basis of statistical raw data, requires numerous transformation steps, recalculations and reallocations. What is more, in some (few) areas of the Energy Balance primary statistics are no longer available, and thus data gaps have to be closed through use of formal estimation methods, applied in accordance with the requirements of each relevant individual case.

18.4.1.1.5 Checking and verification of results

Measures for quality assurance and control cover the following areas:

- Assurance of data quality / transparency of methods and procedures,
- Mechanisms for checking and critically reviewing the Energy Balances, measures that assure the Balances' correctness, completeness and consistency, and
- Measures for documentation and archiving, designed to ensure the Balances' clarity and reproducibility,
- Expert responsibility for preparation of Energy Balances.

Critical discussion, verification and checking of results take place on various levels:

- The Energy Balances Group (Gruppe Energiebilanzen) of DIW Berlin carries out "four-eyes" checks of results and reviews them for plausibility on the basis of control figures (for example, changes in light of annual comparisons, implied net calorific values, utilisation levels).
- In addition, the AGEB member associations carry out supporting checks.
- With regard to renewable energies, the Working Group on Renewable Energy Statistics (AGEE-Stat) carries out its own consultations and "four-eyes" checks.
- The EEFA research institute also cooperates in exchanging, and mutually checking, Energy Balance results.
- Furthermore, at early stages data and results are exchanged and discussed with the DIW's Energy Balance staff and with responsible experts of the Federal Environment Agency (UBA).
- The "Official Mineral Oil Statistics" for Germany (AMS), which are published monthly and annually, imply that the entire system for petroleum production and consumption in Germany is a closed system that is free of internal contradictions. The statistical basis for the AMS is the "Integrated Mineral Oil Report" (IM), which all major oil companies are provided to submit. To fulfill their reporting obligations, oil companies apply extensive models that take account of all "oil streams".
- The Federal Office of Economics and Export Control (BAFA) regularly reviews the data provided by the oil companies. In addition, BAFA also surveys and monitors major traders / importers, a group defined via the "survey group" process. Furthermore, companies that make one-time direct imports are also subject to pertinent reporting obligations.
- The "Official Mineral Oil Statistics" include – apart from a few exceptions – no information on sectoral oil consumption in Germany. Such data are obtained from the aforementioned official and other sources, reviewed and – if necessary – modified. The results must not fall outside of (i.e. be too low or too high) the framework defined by the AMS (production/consumption). So-called "secondary fuels", which are not covered by the AMS, are an exception in this regard.
- The plausibility of oil-consumption data is also checked with the help of indicators.
- The net calorific values for petroleum products and crude-oil inputs are reviewed on an annual basis, and reset as necessary. This process is carried out in light of technical progress and market trends. The aim of the process is to make conversion of tonne data into terajoule units as precise as possible.

- Data and results are exchanged and discussed with the DIW's Energy Balance staff and with responsible experts of the Federal Environment Agency (UBA). The BMWi's "working group on methods" (Arbeitskreis Methodik" – AKM) discusses oil data and different pertinent accounting strategies.

Only when the completed Energy Balance has successfully passed through all controlling bodies is it published on the AGEB's Web site and are provisional Energy Balance data provided to the Federal Environment Agency for further processing within the system for the national greenhouse-gas inventory.

With a view to effective prevention of errors in data calculation and estimation for the Energy Balances, the annual balances are prepared via standardised procedures. To that end, a broad range of instruments has been developed that automate proven estimation procedures, and formal calculation methods, within the context of Energy Balance preparation. This approach, which often permits simple entry of statistical raw data into the suitable calculation tools, largely eliminates calculation and transformation errors. What is more, its use of consistent, standardised methods plays an important role in assuring time-series consistency.

In spite of all its efforts to prepare Energy Balances that are error-free, properly executed and available promptly, the possibility of error cannot be completely ruled out. For this reason, the EEFA research institute carries out the following checks as part of the balance-preparation process:

- Two EEFA staff members independently prepare the annual Energy Balance and then check each other's results,
- The EEFA research institute regularly verifies the Balances' time-series consistency. Where a time series shows implausible jumps that cannot be attributed to transfer or calculation errors, and that must be tied to developments in the underlying primary statistics, the problem is discussed constructively with the relevant data-supplying institution.
- The Energy Balances are cross-checked against the data provided to IEA/Eurostat.
- The AGEB's energy-sector member associations – relative to the Balance sections for which the EEFA research institute is responsible, i.e. the German Coal Importer Association, the Association of the German hard-coal mining industry (GVSt), the DEBRIV Federal German association of lignite-producing companies and their affiliated organisations and the Statistik der Kohlenwirtschaft coal-sector-statistics association – provide constructive critical support, and review and discuss the Balance results.
- Beginning at early stages of Balance preparation, the EEFA Energy Balance staff regularly exchange information and engage in discussion with the responsible experts of the Federal Environment Agency (UBA).
- The Energy Balance results are shared with the German Institute for Economic Research (DIW), a cooperating research institute. The cooperation includes mutual reviewing activities.

18.4.1.1.6 Documentation and archiving

DIW Berlin and the EEFA research institute keep careful, detailed documentation relative to the annual Energy Balances. The documentation covers every Energy Balance entry, lists the statistical sources and surveys used and precisely describes the calculation methods and procedures used.

The purpose of the documentation is to ensure that all steps can be retraced, both by Energy Balance staff and by the persons who use the Energy Balances. Regular updating of the documentation contributes to data quality and helps to assure consistency in time series and methods.

All statistical data, calculation methods and estimation procedures used in preparation of Energy Balances for the Federal Republic of Germany are archived in both electronic and printed form. The pertinent electronic data are backed up automatically by the DIW's central IT department, on dedicated server space, and they are backed up manually at regular intervals. For electronic archiving, EEFA uses portable media (CD-ROMs, DVD), external drives and network-based server systems. Data back-ups are carried out both automatically and manually (at regular intervals).

18.4.1.1.7 Qualified staff

For execution of the service project "Preparation of Energy Balances for the Federal Republic of Germany" ("Erstellen von Energiebilanzen für die Bundesrepublik Deutschland"), DIW Berlin and the EEFA research institute rely on experienced staff with solid backgrounds in the areas of statistics, economics and the energy sector.

18.4.1.1.8 Explanations regarding the currentness and availability of data for preparation of Energy Balances

Official statistics

The final annual data from the monthly survey 066 (electricity generation for the public supply) became available in April 2013. Other annual surveys became available as follows: 064 (heat generation), November 2013; 067 (electricity generation systems of industry), 2013; 070 (electricity feed-in), November 2013; and 073 (sewage gas), August 2013. Nos. 082/082P also became available in November 2013. The results of surveys 066 (electricity generation systems for the public supply) and 067 (electricity generation systems for industry) have to be converted via the "Finnish" method. Calculations, checking and processes of consultation with the German Association of Energy and Water Industries (BDEW), Working Group on Renewable Energy Statistics (Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat), Energy Environment Forecast and Analysis (EEFA) institute, and Association of the German Petroleum Industry (MWV) take at least three weeks.

The results of survey 060 (energy use by industry), which account for a significant part of the Energy Balances, became available in November 2013. That significantly shortened the amount of time available for preparation of the Energy Balance. Calculations for individual sectors, plausibility checks, checking requests submitted to the Federal Statistical Office (which has to forward the requests to the Länder) and consultations with participating associations take at least three weeks. The results of survey 062 (geothermal energy) became available in January 2014.

As a result of such time constraints, an estimated Balance is prepared in July (in a process first carried out for the 2009 report) that incorporates the available official data from survey 066. The remaining data are first estimated and agreed on in cooperation with the AGEB member associations.

Due to methodological changes, it was not possible to use Statistics No. 070 (grid feed-in) in the 2012 balance year (they had been used in previous years). A checking request submitted to the Federal Statistical Office by the German Institute for Economic Research confirmed this. The data on entities feeding into the grid for 2012 are beased in part on data of the ZSW (see below).

Association statistics

The final Energy Balance incorporates data of the associations BDEW, the WEG (flaring losses) and Deutsches Atomforum, data which become available at an early time (from BDEW, in July; from Deutsches Atomforum, in January).

Because quarterly estimates of primary energy consumption in Germany are carried out, provisional data in the relevant areas become available quickly. The BDEW provides important provisional data, dated as of August, that are also of relevance to final energy consumption as recorded in the estimate Balance. Every summer, that organisation publishes data under the heading "The German energy market – facts and figures on the gas, electricity and district-heating sectors" ("Energiemarkt Deutschland – Zahlen und Fakten zur Gas-, Strom- und Fernwärmeversorgung"). In addition, the estimated Balance incorporates BDEW data on gross electricity generation, data of Gesamtverband Steinkohle (GVSt; Association of the German hard-coal mining industry), of the DEBRIV Federal German association of lignite-producing companies and their affiliated organisations, of the Association of the German Petroleum Industry (MWV) and of the Deutsche Atomforum nuclear-energy association.

Other data

For the final Energy Balance, data of the Working Group on Renewable Energy Statistics (Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat), relative to "renewable energy sources", are also used; those data regularly become available in July/August.

The 2012 figures on electricity generation from biomass, and on biomass-fuel inputs decentralised CHP systems, are based on data and indexes of the Centre for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW). In this connection, a method is used that was developed by ZSW and EEFA in the framework of reporting to IEA and Eurostat.

For 2012, in calculation of electricity generation and fuel inputs in small CHP systems fired with natural gas and HEL (< 1 MW), first-time use was made of figures from the BHKW (compact combined heat-and-power (CHP) generating systems) database of the Öko-Institut e.V. Institute for Applied Ecology. The same figures are used for reporting in the IEA/Eurostat context.

In the area of wood consumption by private households (as of 2010), the RWI/forsa survey carried out under commission to the BMWi serves as the database.

The methodological changes relative to decentralised biomass systems necessitate revisions in the Energy Balances in the period 2003-2011. The methodological changes made in the 2012 Energy Balance have been set forth in detail in a separate paper of DIW Berlin of 10 March 2014.

Table 372: Federal Statistical Office surveys used in preparation of Energy Balances for the Federal Republic of Germany

Survey	No.	Survey period	Currentness, pursuant to quality report	Type of data	Group surveyed	Units surveyed
Survey of energy use by the mining, quarrying and manufacturng sectors	060	Annually	End of the following year *(available as of the end of October / beginning of November)*	Electricity generation, deliveries and consumption **Fuels / energy sources, orders and consumption, by energy source / fuels** **Fuels / energy sources, deliveries and stocks, by energy source / fuels** Average net calorific value	Sections B "Mining and quarrying" and C "Manufacturing"	**Producing companies** (currently, at least 40,000) with **at least 20 employees** **Exception:** Plants of Manufacturing sector companies with **10 or more persons active in the relevant economic sectors**
Survey on geothermal energy	062	Annually	About 9 weeks after the end of the reporting period	**Net heat generation** and output by type of system, and by domestic customer groups being supplied with heat.		The survey covers a maximum of **100 operators of systems for use of geothermal energy**
Survey of heat generation, demand, use and supply,	064	Annually	End of the following year *(available usually at the end of September)*	District heating: Net heat generation, demand, deliveries and network losses. No information on energy sources / fuels is provided Heating plants: **Fuel inputs and heat production, by energy sources / fuels**	Operators of **heating plants** with outputs of at least 1 MWth, and operators of **district heating networks** (only large networks that have grown "historically"). No **"island networks" for district heating are surveyed**	**Max. of 1,000 operators** of heating plants, including absorption systems for refrigeration, and with outputs of **at least 2 MW_{th}.**
Survey of electricity and heat generation of electricity generation systems serving the public grid	066K	Monthly; annually	6 weeks after the end of the reporting period; end of June of the following year *(available in May)*	Number, net-electricity and net-heat production, by plant type, **Electricity and heat production, by energy sources / fuels** **Fuel inputs for electricity and/or heat production, by energy sources / fuels** (separate survey of CHP systems)	Companies and plants in the **electricity sector (public grid)**	**Max. of 1,000 operators of plants with outputs of at least 1 MW_{el}.**
Survey of electricity generation systems of manufacturing, mining and quarrying companies	067	Annually	9 weeks after the end of the reporting period *(available usually at the end of September)*	**Number and bottleneck capacity, by plant type** **Net-electricity and net-heat production (separate survey of CHP systems)** **Fuel inputs for electricity and/or heat production, by energy sources / fuels (separate survey of CHP systems)** Own consumption of electricity and heat	Sections B "Mining and quarrying" and C "Manufacturing"	Operators (currently, about 500) of **systems serving their own requirements**. Surveys cover systems for generating electricity, including systems for co-generation of electricity and heat (CHP) with **outputs of at least 1 MW_{el}**
Survey of network operators relative to electricity feed-in	070	Annually	12 weeks after the end of the reporting period *(available usually at the end of September)*	**Electricity feed-in, by Länder and energy sources / fuels** **Power statistics, separately for Länder and energy sources / fuels**	Operators of electricity grids for the public supply	**Exhaustive survey**
Survey of production, use and supply of sewage gas	073	Annually	8 weeks after the end of the reporting period *(available at the end of June / beginning of July)*	**Anaerobic sewage-gas collection** **Fuel inputs in power stations** **Fuel inputs for heating only or motors (drive units) only** **Electricity feed-in** **Own consumption**	Operators of wastewater-treatment plants	Max. of 6,000 operators of wastewater-treatment plants (currently, **about 1,300 operators**)
Survey on provision of liquefied petroleum gas	075	Annually	8 weeks after the end of the reporting period *(available at the end of June / beginning of July)*	**Provision of liquefied petroleum gas, by domestic customer groups and German Länder (states); and exports**	Companies that provide liquefied petroleum gas to end users and resellers	A maximum of 130 companies that provide liquefied petroleum gas to end users or resellers
Survey of production, supply, import and export of gas, and of revenue of gas utilities and gas sellers	082	Annually	National results become available 12 months after the end of the period covered by the report	**Extraction and production of gas, demand for gas, and value of relevant imports** **Deliveries and exports of gas, and relevant revenue** **Gas production, by gas types** **Gas deliveries, and revenue, by Länder**	Gas-sector companies	Exhaustive survey
Survey of supply, import and export of natural gas and petroleum gas, and of revenue of producers	082P	Annually	National results become available 12 months after the end of the period covered by the report	**Imports and exports; sales by domestic customer groups**	Natural gas producers	Exhaustive survey

Link to the nomenclature for classification of industrial sectors (Nomenklatur der Wirtschaftszweige; WZ 2008): https://www.destatis.de/DE/Methoden/Klassifikationen/Klassifikationen.html

Link to the quality reports on energy statistics, and a questionnaire: https://www.destatis.de/DE/Publikationen/Qualitaetsberichte/Energie/EnergieWasserversorgung.html

18.4.1.1.9 Methodological changes in the 2012 Energy Balance

Ingrid Wernicke, Jochen Diekmann, May 2014

In connection with complete coverage of decentralised CHP systems, questionnaire officials developed methodological changes and estimation approaches for reporting to IEA/Eurostat. These changes and approaches were used for the first time in the questionnaires (JAQ) for 2012 and for reviews for the period 2003 through 2011. Similar changes have entered into the 2012 Energy Balance. A number of minor adjustments have also been made to the Energy Balance.

In particular, the following changes were made in the **2012 Energy Balance**:

- Small biomass CHP systems: The fuel inputs are now calculated via a new method, using indexes of ZSW (CHP shares, electricity-utilisation factors, electricity indexes), and, in accordance with the pertinent Finnish method, are divided in accordance with electricity and heat generation. The fuel inputs for electricity are listed as transformation inputs in Energy Balance line (EBZ) 14, while those for heat are listed as final energy consumption in the Commercial and Institutional sector (in EBZ 67). In general, this procedure is used for solid biomass; liquid biogenic substances; and sewage gas, biogas and landfill gas (in the case of solid biomass, part of the fuel inputs are offset against consumption in the wood industry). Under the new method, as a result of higher utilisation levels, biomass consumption for primary energy (not including waste and sewage gas) has decreased by 224 PJ (of which 105 PJ are biogas). This has reduced total primary energy consumption (PEC) by 1.6 %.
- Compact CHP systems fired with natural gas and heating oil: For the first time, electricity from small CHP systems (< 1 MW) is being recorded. The pertinent database consists of the CHP monitoring data (KWK-Monitoring-Daten) of the Öko-Institut, data which are also used by the BDEW. The fuel inputs for CHP electricity are recorded as transformation inputs (in Energy Balance line 14) and deducted from the final energy consumption in the Commercial and Institutional sector (EB line 67), since it is assumed that all sales to Commercial and Institutional are included in that final consumption. This change does not change the primary energy consumption.
- Geothermal: a) electricity generation (pursuant to Strerz and annual invoices under the Renewable Energy Sources Act (EEG)) is assessed with a primary-energy efficiency of 10 % (as is customary internationally); b) heat generation in combined heat and power (CHP) stations is determined, on the basis of surveys 064 and 066, and as of the 2012 EB, of the geothermal survey (062); c) in addition, as of 2012 geothermal heat for spas (pursuant to GeotIS) is taken into account in the Commercial and Institutional sector; a heat effficiency of 50 % is applied. As a result of the lower efficiencies involved, the primary energy consumption has increased by 2.4 PJ.
- Wood consumption in the residential sector: The figures for wood consumption by the residential sector are based on data collected in a survey of RWI. No figures are being entered for the Commercial and Institutional sector pending a pertinent decision of the Working Group on Energy Balances (AGEB).
- Solar-thermal systems and heat pumps: Pursuant to ZSW, shares of 93.73 % and 95 %, respectively, are assumed for the residential sector.
- Biomethane in road transports: Use of biomethane in road transports is now included (in keeping with ZSW, on the basis of energy-taxation statistics and statistical data relative to fulfillment of the biofuels-admixture requirements. This increases the primary energy consumption by 1.3 PJ.

- Natural gas accounting: In addition to natural gas, survey 082 also covers other gases, especially biomethane and coke oven gas. For the 2012 Energy Balance, the German Association of Energy and Water Industries (BDEW) has specifically calculated, for the first time, biomethane and coke-oven-gas sales from final energy consumption of the residential and Commercial and Institutional sectors. In the Energy Balance, biomethane is listed under biogas.
- Gross electricity generation: In connection with the new method for bio- CHP systems, and inclusion of fossil-fired mini- CHP systems, changed gross electricity-generation quantities have resulted. These are already included in the pertnent BDEW figures (revision for the period as of 2003).
- Electricity grid losses: The grid losses are now recorded solely in keeping with the pertinent data of the Federal Statistical Office; i.e. the "not included" ("Nichterfasstes") section of the BDEW balance is not included.
- Electricity consumption by industry: No own consumption by power stations is deducted from electricity consumption by industry (pursuant to survey 060).
- Electricity consumption in transports: The revised data of the BDEW are used (for 2012, about 12 TWh, instead of about 17 TWh).

With these changes, the national Energy Balance has been largely brought into line with the questionnaires for IEA/Eurostat and the BDEW's "Strerz" data.

18.4.1.2 Comparison of the 2012 Estimated Energy Balance (provisional) with the 2011 Energy Balance (final)

The AGEB normally publishes the final Energy Balances in the spring of the next calendar year but one. With a view to providing data at earlier times, as of 2009 estimated Energy Balances are being prepared along with the evaluation tables. In some cases, those balances are based on different data sources (cf. the quality report of DIW and EEFA, April 2013).

In the framework of the UNFCCC's review of Energy Balances, with respect to quality control and assurance, careful attention is given to discrepancies between final Energy Balances and estimated Energy Balances (most recently, in April 2013, for 2011). In addition, the estimated Energy Balance for 2012 has been compared with the 2011 Energy Balance (see below).

In such comparisons, both absolute and relative discrepancies are calculated, to make it possible to identify any significant discrepancies between final and provisional Energy Balances. Such significant discrepancies have to be individually explained. The occurring numbers of discrepancies, for Energy Balance lines and Energy Balance columns, have been analysed in light of a combination of the criteria "discrepancies in TJ" and "discrepancies in %". In such analysis, the combined occurrence of a discrepancy of 10,000 TJ and 20 % seems to be a suitable threshold above which discrepancies have to be explained.

The differences between the 2012 estimated Energy Balance and the 2011 Energy Balance 2010 are in keeping with the differences, with respect to the previous year, that were foreseeable at the time the estimated Energy Balance was prepared. The general reasons for such differences include economic trends, structural changes, changes in prices, weather-related effects and special developments such as the decision to discontinue use of nuclear power. Such general trends in energy consumption and its determining factors in 2011, in comparison to the corresponding aspects in 2010, are discussed in the annual report of the Working Group on Energy Balances (AG Energiebilanzen; 2013).[168]

In addition, it must be noted that data discrepancies can occur in that other data sources have to be used to prepare the estimated Energy Balances, in some cases, than are used to prepare the final Energy Balances. Furthermore, differences can occur as a result of changes in methods.

The comparison of the Energy Balances serves the primary purpose of checking and documenting the plausibility of noticeable changes. In some Balance positions, changes determined via the aforementioned criteria are simply not unusual, however. For example, this applies to changes in stocks, which by nature differ significantly from year to year.

The Federal Environment Agency has received an overview, with explanations, of conspicuous positions that resulted in the comparison of the 2011 Energy Balance and the 2012 estimated Energy Balance. The overview details the key results of the comparison.

18.4.1.3 Comparison of the 2011 Energy Balance (final) with the 2012 Estimated Energy Balance (provisional)

The AGEB normally publishes the final Energy Balances in the spring of the next calendar year but one. With a view to providing data at earlier times, as of 2009 estimated Energy Balances are being prepared along with the evaluation tables. In some cases, those balances are based on different data sources (cf. the quality report of DIW and EEFA, April 2013).

In the framework of the UNFCCC's review of Energy Balances, with respect to quality control and assurance, careful attention is given to discrepancies between final Energy Balances and estimated Energy Balances.

In such comparisons, both absolute and relative discrepancies are calculated, to make it possible to identify any significant discrepancies between final and provisional Energy Balances. Such significant discrepancies have to be individually explained. The occurring numbers of discrepancies, for Energy Balance lines and Energy Balance columns, have been analysed in light of a combination of the criteria "discrepancies in TJ" and "discrepancies in %". In such analysis, the combined occurrence of a discrepancy of 10,000 TJ and 20 % seems to be a suitable threshold above which discrepancies have to be explained.

The Federal Environment Agency has received an overview, with explanations, of conspicuous positions that resulted in the comparison of the 2011 Energy Balance and the 2012 estimated Energy Balance. The overview details the key results of the comparison.

18.4.1.4 Comparison of the 2013 Estimated Energy Balance with the 2012 Energy Balance

Diekmann, Wernicke (DIW Berlin), Buttermann, Baten (EEFA), Rossbach, 25 September 2014

The AGEB normally publishes the final Energy Balances in the spring of the next calendar year but one. With a view to providing data at earlier times, as of 2009 estimated Energy Balances are being prepared along with the evaluation tables. In some cases, those balances are based on different data sources (cf. the quality report of DIW and EEFA, April 2013).

[168] AG Energiebilanzen (Working Group on Energy Balances): Energieverbrauch in Deutschland im Jahr 2012 (energy consumption in Germany in 2011). Cool temperatures brought about a slight increase in primary energy consumption in 2012. March 2013. www.ag-energiebilanzen.de

In the framework of the UNFCCC's review of Energy Balances, with respect to quality control and assurance, careful attention is given to discrepancies between final Energy Balances and estimated Energy Balances (most recently, in March 2014, for 2012). In addition, the estimated Energy Balance for 2013 has been compared with the 2012 Energy Balance (see below).

In such comparisons, both absolute and relative discrepancies are calculated, to make it possible to identify any significant discrepancies between final and provisional Energy Balances. Such significant discrepancies have to be individually explained. The occurring numbers of discrepancies, for Energy Balance lines and Energy Balance columns, have been analysed in light of a combination of the criteria "discrepancies in TJ" and "discrepancies in %". In such analysis, the combined occurrence of a discrepancy of 10,000 TJ and 20 % seems to be a suitable threshold above which discrepancies have to be explained. With these criteria, the comparison of the 2013 estimated Energy Balance with the 2012 Energy Balance yields 39 positions (including sum fields). These are shown in the overview. The various positions are explained in detail in the following.

The differences between the 2013 estimated Energy Balance and the 2012 Energy Balance 2010 are in keeping with the differences, with respect to the previous year, that were foreseeable at the time the estimated Energy Balance was prepared. The general reasons for such differences include economic trends, structural changes, changes in prices, weather-related effects and special developments such as the decision to discontinue use of nuclear power. Such general trends in energy consumption and its determining factors in 2013, in comparison to the corresponding aspects in 2012, are discussed in the annual report of the Working Group on Energy Balances (AG Energiebilanzen; 2014).[169]

In addition, it must be noted that data discrepancies can occur in that other data sources have to be used to prepare the estimated Energy Balances, in some cases, than are used to prepare the final Energy Balances. Furthermore, differences can occur as a result of changes in methods.

The comparison of the Energy Balances serves the primary purpose of checking and documenting the plausibility of noticeable changes. In some Balance positions, changes determined via the aforementioned criteria are simply not unusual, however. For example, this applies to changes in stocks, which by nature differ significantly from year to year.

Table 373: Overview: Questionable positions resulting from the comparison of the 2013 estimated Energy Balance and the 2012 Energy Balance – changes 2013 (provisional) with respect to 2012 (final)

	EB line	TJ	%
Hard coal	Domestic production	-96,450	-29.7
Hard coal	Removals from stocks	-10,843	-93.0
Hard coal	District heating stations	-16,575	-48.9
Hard coal	Statistical differences	16,056	143.2
Other StKP	Imports	-46,218	-100.0
Other StKP	Domestic energy production	-46,218	-100.0
Other StKP	Exports	-54,515	-100.0
Other StKP	Other energy producers	-12,877	-100.0
Other StKP	Total transformation inputs	-12,877	-100.0
Other StKP	Coking plants	-13,518	-100.0
Other StKP	Other energy producers	-11,830	-100.0
Other StKP	Total transformation emissions	-25,349	-100.0

[169] AG Energiebilanzen (Working Group on Energy Balances): Energieverbrauch in Deutschland im Jahr 2013 (energy consumption in Germany in 2011). Cool temperatures brought about a slight increase in primary energy consumption in 2013. March 2014. www.ag-energiebilanzen.de

	EB line	TJ	%
Diesel fuel	Imports	166,881	49.4
Diesel fuel	Removals from stocks	-12,573	-100.0
Diesel fuel	Domestic energy production	154,308	44.1
Diesel fuel	Exports	47,014	24.7
Diesel fuel	DOMESTIC PRIMARY ENERGY CONSUMPTION	107,189	76.0
HEL	Mining, non-metallic minerals, manufacturing sector overall	14,535	29.2
HS	Removals from stocks	18,066	---
HS	Domestic energy production	22,597	23.5
HS	Exports	27,169	32.8
HS	Additions to stocks	-16,194	-100.0
HS	DOMESTIC PRIMARY ENERGY CONSUMPTION	21,510	-23.8
HS	FINAL ENERGY CONSUMPTION	10,538	49.8
HS	Transport equipment	10,611	---
HS	Mining, non-metallic minerals, manufacturing sector overall	10,612	50.5
Natural gas	Thermal power stations for the public supply	-70,645	-21.5
Natural gas	Statistical differences	-84,025	-401.7
Natural gas	Commercial and institutional, and other consumers	85,400	23.5
Biomass	Imports	-12,291	-25.2
Electricity	DOMESTIC PRIMARY ENERGY CONSUMPTION	-38,548	46.4
PET	Removals from stocks	-15,516	-52.3
PET	Statistical differences	-62,546	-246.8
PET	Commercial and institutional, and other consumers	90,976	20.0
SET	Removals from stocks	13,754	31.4
SET	Additions to stocks	-23,393	-64.7
SET	DOMESTIC PRIMARY ENERGY CONSUMPTION	190,206	41.4
Total	**Additions to stocks**	**-30,547**	**-41.2**
Total	**Statistical differences**	**-71,222**	**316.3**

Explanatory remarks:

Hard coal

Production: Domestic production has been decreasing.

District heating stations: Reduction of fuel inputs for uncoupled heat generation in combined heat and power (CHP) stations, pursuant to survey 066.

Other hard-coal products

According to coal associations, as of 2013 other hard-coal products are no longer being separately listed. In keeping with the fact that the statistical basis for these products has gradually been disappearing, a majority of the data has been based on estimates. What is more, these products are not reported internationally. Since these products are used exclusively for non-energy related uses, their relevance for the Energy Balance is not particularly high.

Diesel fuel

The data for 2012 and 2013 have been confirmed (AMS). Diesel consumption in Germany increased in 2013. This has been due primarily to increases in transports. Since German refineries' diesel production has been relatively low, and since exports have increased, the German oil industry has had to import more than in the previous year. In balance, consumption of diesel fuel for primary energy has increased sharply.

Light heating oil

The data have been confirmed. HEL consumption in the other mining and manufacturing sectors is relatively low. Added consumption has been triggered by economic growth and by low prices for HEL.

Heavy fuel oil

Consumption of heavy fuel oil (HS) for non-energy-related purposes has dropped considerably (-15 %). Exports of HS increased by 34%. Production by German refineries was about 7 % lower in 2013. The data on the HS final energy consumption are still highly provisional; they have been estimated on the basis of industry notifications.

Natural gas

Natural-gas-based electricity generation in thermal power stations for the public supply has decreased sharply.

Natural gas consumption in the Commercial and Institutional sector has increased sharply, as a result of lower temperatures.

Biomass

The Federal Office of Economics and Export Control (BAFA) reports that biomass imports have decreased.

Electricity

The export surplus has increased.

Primary energy sources (PET), secondary energy sources (SET), total

The changes in stocks lie with the normal fluctuation range.

Statistical differences have been calculated as differences.

An increase in the Commercial and Institutional sector, especially as a result of increased natural gas consumption.

18.5 Energy-Data Action Plan for inventory improvement

Also in 2012, the Federal Environment Agency, working in cooperation with the Federal Ministry for Economic Affairs and Energy (BMWi), the Working Group on Energy Balances (AGEB) and the Federal Statistical Office, prepared an "Energy-Data Action Plan for inventory improvement" that outlined actions to be taken to address the criticism that emerged from the inventory review. This action plan fulfills the action-plan requirement set forth in Paragraph 39 of the 2011 review report (FCCC/ARR/2011/DEU).

Table 374: Energy-Data Action Plan for inventory improvement

No.	Issue	Responsi-bility	Responsibility for execution	Ref-erence (para-graph)	Quotation from 2011 review report (FCCC/ARR/2011/DEU)	Instrument for implementa-tion / publication	Activity for improvement	Result planned / achieved	Time frame	Remark
1	Energy-Data Action Plan for inventory improvement	Federal Ministry for Economic Affairs and Energy (BMWi) / UBA / AGEB / Federal Statistical Office	UBA	39	address review relevant issues in an action plan in the 2011 submission. […] The ERT reiterates the recommendation of the previous review report that Germany prepare a plan for the remaining abovementioned issues, and to report on it and on any progress achieved in its next annual submission	Action plan; NIR	The pertinent action plan is being prepared, for the first time, for the 2013 inventory report	A coordinated Energy-Data Action Plan for inventory improvement is available for the 2012 inventory review process and will be updated annually	Ongoing	
2.1	Deadline compliance of the final Energy Balance	BMWi / AGEB / persons responsible for questionnaire / Federal Statistical Office / statistical offices of the Länder	BMWi	39	timeliness of reporting […]	Process analysis, energy data; NIR	For the 2013 inventory report, a process analysis is presented. Inter alia, it covers reporting channels (these are described more precisely than in the past), the efforts made to shorten such channels and the relevant success achieved.	Process analysis, describing applicable reporting channels more precisely than in the past, and describing efforts made to shorten such channels and the relevant success achieved, enables review experts to determine that	Completed	

No.	Issue	Responsi-bility	Responsibility for execution	Ref-erence (para-graph)	Quotation from 2011 review report (FCCC/ARR/2011/DEU)	Instrument for implementa-tion / publication	Activity for improvement	Result planned / achieved	Time frame	Remark
								Germany has made use of all available possibilities for optimisation; the status of relevant work is described in the NIR 2013.		
2.2	Deadline compliance of the final Energy Balance	BMWi/AGEB/Federal Statistical Office/Statistical offices of the Länder	BMWi/AGEB (not for official data)/Federal Ministry for Economic Affairs and Energy (BMWi) and statistical offices of the Länder (for official data); persons responsible for questionnaires	137	In the course of the review, the ERT formulated a number of recommendations relating to the transparency of background and methodological information (e.g. in the energy[...] sectors), justification and documentation of recalculations (e.g. in the energy[...] sectors)[...] The key sectoral recommendations are that Germany: [...] (b) Improve the timeliness of reporting of the NEB (energy);	Process analysis, energy data; NIR	Organisational improvements in the statistical offices of the Länder. In rapporteurs' meetings with the Länder, the Federal Statistical Office discusses possibilities and ways of improving the cooperation.	In future, official statistics are to be transmitted at an earlier time than has been the case to date.		
3.1	Discrepancies between provisional and final EB	BMWi / AGEB / persons responsible for questionnaire / Federal Statistical Office / statistical offices of the Länder	AGEB; UBA	39	significant differences between the preliminary and final NEB	QC report; NIR	Energy data consistency analysis (EDKA)	Identification and clarification of discrepancies, along with differentiation and addressing of a) Informational deficits b) Documentation requirements c) Data problems d) Methodological changes	Ongoing	

No.	Issue	Responsibility	Responsibility for execution	Reference (paragraph)	Quotation from 2011 review report (FCCC/ARR/2011/DEU)	Instrument for implementation / publication	Activity for improvement	Result planned / achieved	Time frame	Remark
3.2	Discrepancies between provisional and final EB	AGEB	AGEB	39	significant differences between the preliminary and final NEB	QC	The AGEB is working to reduce estimation errors.	Reports of the AGEB regarding plausibility checks. The AGEB reviews new procedures and methods for preparing the estimated Energy Balance. Specific proposals in this regard have been made (cf. the report of the EEFA research institute regarding approaches in estimation and modelling for the preparation of provisional Energy Balances.	Ongoing	
3.3	Discrepancies between provisional and final EB	AGEB, UBA	UBA	39	significant differences between the preliminary and final NEB	NIR	In the 2014 National Inventory Report (NIR), the possibilities for reducing such discrepancies are described, and the pertinent results will be presented in the framework of a "differences discussion". In September, in the runup to the 2012 inventory review, significant differences will be explained, and initial information will be provide to review experts.	The status of such work is documented in the NIR 2014: Documentation, revision of data for earlier years, reduction of estimation errors	September 2012, 2013 (NIR)	
4	Complex National System	Federal Ministry of Economics	UBA	39	The previous review report noted several issues related to	NaSE	Exchange regarding the results of the inventory	Energy-data workshop on 16 Nov. 2010 Energy-data workshop		

No.	Issue	Responsi-bility	Responsibility for execution	Ref-erence (para-graph)	Quotation from 2011 review report (FCCC/ARR/2011/DEU)	Instrument for implementa-tion / publication	Activity for improvement	Result planned / achieved	Time frame	Remark
		and Technology (BMWi) / UBA / AGEB			Germany's NEB (such as [...] the complexity of the NEB compiling process that may contribute to the problems with regard to timeliness and quality.		review and derivation of requirements for action;	on 5 August 2011 Energy-data workshop on 27 April 2012 Energy-data workshop on 7 August 2012 Energy-data workshop 2013		
5	Quality assurance	EEFA / German Institute for Economic Research (DIW) / Federal Statistical Office / AGEB / UBA	AGEB / UBA	39	lack of QA/QC procedures in place for some data sources used to compile the NEB	NIR	Joint AGEB quality report in the new Annex 2 of the NIR 2012 and in subsequent inventory reports	the NEB is subject to QA/QC procedures in accordance with the national system	Ongoing since 2012	
6.1	Discrepancies between EB and IEA data	BMWi, AGEB, persons responsible for questionnaires	BMWi	39	low comparability with the IEA data		To be jointly defined in the framework of the action plan	Introduction of a transition procedure for assuring compatibility between the Energy Balance and surveys in the areas of electricity and heat (cf. in this regard the report of the EEFA research institute to the AGEB and the Federal Ministry for Economic Affairs and Energy (BMWi). The transition has been successfully carried out as part of comprehensive revision of the questionnaires. Efforts to minimize discrepancies are	Completed or ongoing Completed Spring 2014	

No.	Issue	Responsibility	Responsibility for execution	Reference (paragraph)	Quotation from 2011 review report (FCCC/ARR/2011/DEU)	Instrument for implementation / publication	Activity for improvement	Result planned / achieved	Time frame	Remark
								being continued in other areas of the surveys and the Energy Balance. AGEB reports on plausibility checks Revision of the questionnaire for 2003-2011. Planned revision of the NEB		
6.2	Discrepancies between EB and IEA data	BMWi, AGEB, persons responsible for questionnaires	BMWi	45	The ERT also noted differences between the inventory data and the corresponding IEA data (e.g. for solid fuels exports, the data show differences of over 60 per cent in some recent years […] Germany has provided some explanations for the divergences and informed the ERT that it is continuing to investigate these differences. The ERT considers that the differences cause no underestimation of emissions, but reiterates the recommendation of the previous review report that Germany explain the reasons for these differences between its inventory		To be jointly defined in the framework of the action plan	See 6.1		

No.	Issue	Responsi-bility	Responsibility for execution	Ref-erence (para-graph)	Quotation from 2011 review report (FCCC/ARR/2011/DEU)	Instrument for implementa-tion / publication	Activity for improvement	Result planned / achieved	Time frame	Remark
					data and the corresponding IEA data in its next annual submission.					
7.1	Improvement of the balance sheet for gases	BMWi / Federal Statistical Office / DIW / UBA / and others	Federal Statistical Office	39	significant amount of flaring/losses of natural gas in the NEB that were not transparently accounted for	NIR, EB	Meeting involving all participating energy experts; review and adjustment of the data source	The significant amount of flaring/losses of natural gas are taken into account	Apr 12	Completed
7.2	Improvement of the balance sheet for gases	BMWi / Federal Statistical Office / DIW / UBA / and others	Federal Statistical Office	39	significant amount of flaring/losses of natural gas in the NEB that were not transparently accounted for	NIR, EB	Updating of the gas balance sheets in the positions relative to flaring losses, and in positions relative to production, foreign trade, changes in stocks, non-energy-related consumption and energy-related consumption, in the Energy Balances for 2005 and for subsequent years	The significant amount of flaring/losses of natural gas are taken into account with regard to the time series Revision of the NEB	Completed	

18.6 Uncertainties in the activity rates for stationary combustion systems

See NIR 2007, Chapter 13.6.

18.7 CO_2 emissions

The CO_2 emission factors have been completely revised for the 2015 report. For the first time, such work was able to draw extensively on data from emissions trading. Emissions trading data were available on relevant calorific values, emission factors, fuel quantities and data quality. The data were subjected to thorough quality control. For example, only factors on level 3 or 4 (measurement) entered into the calculations. In addition, emission factors were sorted out if it was clear that they had simply been taken from lists. In emissions trading, some substance flows are not unambiguously named, and this can lead to erroneous material allocations in solid fuels categories. With regard to coal, it was possible to identify such misallocations, via the pertinent net calorific values, and then carry out the necessary resorting. Lignite and hard coal can be clearly differentiated via net calorific values. Annually weighted average values were calculated from the quality-checked data. To make it possible to determine whether the resulting factors are representative, the underlying fuel quantities were compared with the corresponding quantities in the Energy Balance. In addition, every effort was made to achieve the greatest possible consistency between net calorific values and emission factors.

Other data sources, in addition to the data from emissions trading, were evaluated as well. Furthermore, archive data were reviewed and measurements of our own were carried out. The recalculations through 1990 were carried out with widely differing procedures, chosen in each case in accordance with the specific subject area. This was done with a view to assuring time-series consistency and to obtaining the most realistic solutions possible. The task of finding well-documented archive data for the year 1990 presented a special challenge, since the documents from that period are available only in paper form and are housed at various different institutions. What is more, data are seldom kept for a period of longer than 20 years.

Since no reliable and representative data are available on the carbon content remaining in ash, an oxidation factor of 1 has been assumed. That figure is also the default value in the 2006 IPCC Guidelines.

18.7.1 Hard coal

For hard coal, an inter-sectoral emission factor has been calculated. In the present case, this ensures that the total emissions are determined as precisely as possible. One exception in this case consists of the coking coal for the iron and steel industry, which differs considerably from steam coal. Another exception consists of the anthracite coal used in the residential sector and in other small combustion plants; that coal has considerably higher calorific values and carbon-content levels.

For the other types of hard coal, emissions trading data from the years 2005 – 2013 were evaluated. For each type, there are substance flows that can be correlated with specific areas of origin. This makes it possible to determine origin-specific CO_2 emission factors and calorific values. Apart from the coal for which origin-specific data are available, there are quantities of mixed coal, and of coal of uncertain origin, to consider. CO_2 emission factors and calorific values were determined for all individual coal fractions (Germany, South Africa, Australia, Indonesia, Columbia, Norway, Poland, Czech Republic, Russia, the U.S. and Venezuela). In addition, weighted averages were calculated for the other hard-coal types for which specific values cannot be obtained. Two different methods for recalculating the emission factors for hard coal were reviewed. On the one hand, a weighted average for each year was calculated with the help of the data on the various individual areas of origin and the import-flow figures from hard-coal statistics. On the other, a weighted average was formed from all of the emission factors reported and checked in the emissions trading framework. The following figure shows the results of this comparison:

Table 375: Comparison of CO_2 emission factors for hard coal

[t CO2/TJ]	2005	2006	2007	2008	2009	2010	2011	2012	2013
Calculation via imports	93.874	93.976	93.865	93.924	93.993	94.003	94.181	93.652	93.280
Weighted EF from all ETS data	93.606	93.940	93.792	94.317	94.121	94.032	94.228	93.675	93.363
Difference	**0.29%**	**0.04%**	**0.08%**	**-0.42%**	**-0.14%**	**-0.03%**	**-0.05%**	**-0.02%**	**-0.09%**

Since the differences are very small in most years, as of the year 2006 the weighted emission factors for all hard coal reported in the emissions trading framework (apart from that in the iron and steel sector) can be used – regardless of the area of origin involved. For the recalculation through 1990, the origin-specific emission factors calculated from emissions trading data are combined with the relevant import flows. This produces a consistent time series.

The following figure shows the evaluatable hard-coal quantities for which emission factors and calorific values were available that were measured in the emissions trading framework.

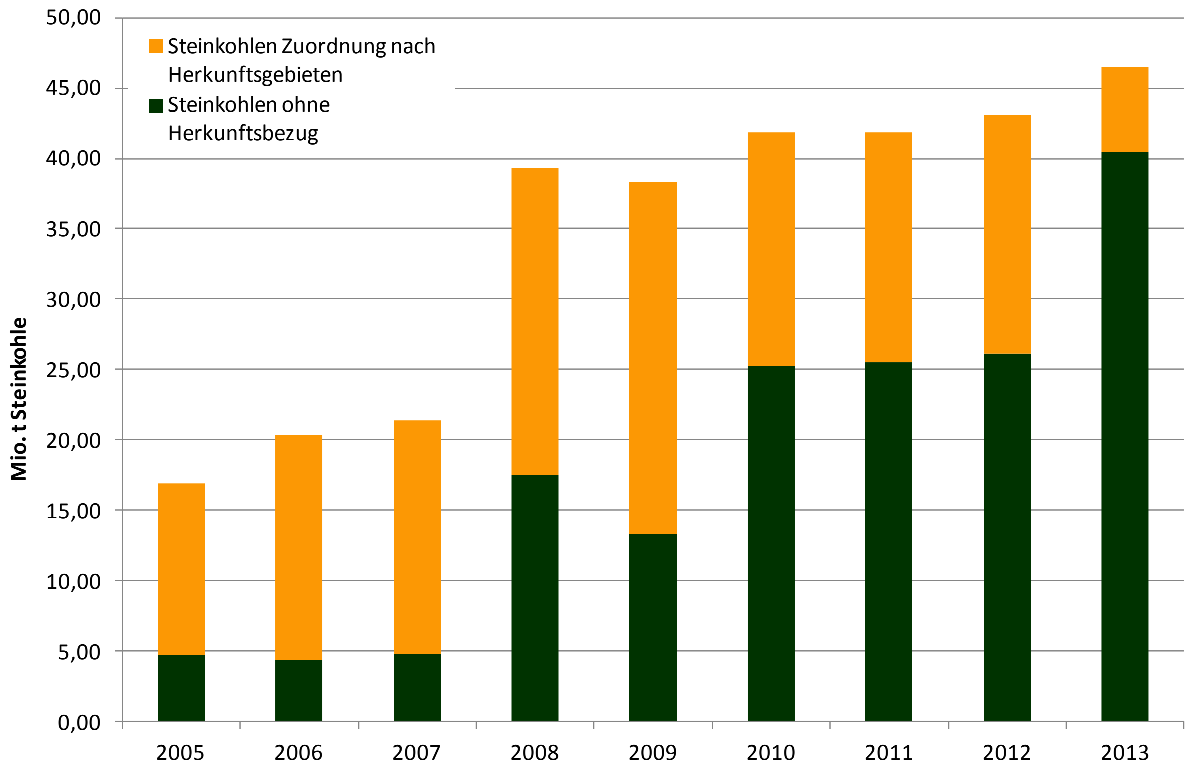

Figure 82: Hard-coal quantities for the emission factors and calorific values measured in the emissions trading framework [Hard coal allocated to specific areas of origin; Hard coal without allocation to area of origin; y axis = Millions of tonnes of hard coal]

It emerges that the quality of the values increases – especially so as of the year 2008 – due to changes in regulations. Furthermore, the quantity of hard coal that can be clearly allocated to a specific mining area decreases noticeably. For this reason, the most sensible approach, from a technical standpoint, is to form a weighted average for all hard coal, regardless of area of origin. This is the only way to ensure that the emission factors are representative. Fortunately, the results of the two calculation approaches hardly differ at all to date.

All in all, very thorough quality checks were conducted, and numerous evaluations were carried out. As the following figure illustrates, it is possible to develop fairly clear origin profiles, and there is a clear relationship between carbon content and net calorific value.

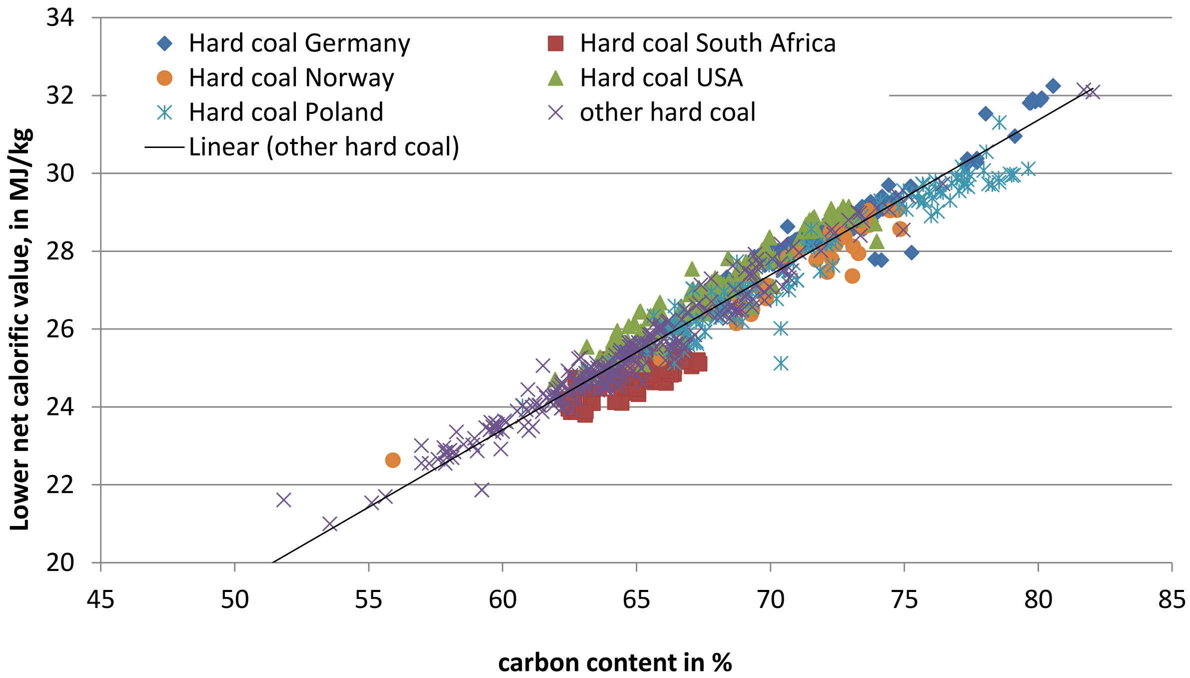

Figure 83: Relationship between carbon content and calorific values, for various qualities of hard coal

Most types of hard coal have a carbon content of between 60 and 75 %. The average, depending on the year concerned, lies between 65 and 66 %. The hard coal in the lower range, with a carbon content as low as 56 %, and a net calorific value of no more than 22 MJ/kg, can be referred to as "high-ballast coal". The hard coal in the upper range, as of a net calorific value of about 30 MJ/kg, is of coking-coal quality. The highest carbon-content levels are found in anthracite.

The figure does not include values for the **coking coal** used in Germany. Coking coal was evaluated separately, due to its special characteristics. In addition, no evaluatable net calorific values are reported, with regard to coal in the emissions trading framework, for the iron and steel industry. As a result, only weight-based emission factors have been determined for that area. Consequently, the coal quantities in that area have also been recorded in terms of tonnes. Since the available statistics give virtually no pertinent calorific-value figures, it seems useful to calculate with natural units. With the help of intensive discussions with the responsible experts of the German Emissions Trading Authority (DEHSt), it proved possible to determine representative emission factors for the hard coal used in the iron and steel industry. From the same data set, combined emission factors were developed for **hard-coal coke, hard-coal tar and benzene**, which in the Energy Balance are listed under "other hard-coal products".

With regard to **hard-coal coke**, an average, energy-based CO_2 emission factor was calculated, for all other industrial sectors, from the emissions trading data for the years 2005 – 2013.

Since emissions trading statistics do not cover the **hard-coal briquettes** used in small combustion plants, we carried out our own analyses for that area, in the framework of a project. The resulting values have been entered back through the year 1990, since no representative values are available for the base year.

18.7.2 Lignite

The raw lignite used for electricity generation for the public grid can be allocated, via lignite statistics, to specific coalfields. For the period as of the year 2005, the CO_2 emission factors are determined from emissions trading data. Those data, as provided, are also broken down by specific coalfields. The following figure provides an illustrative example:

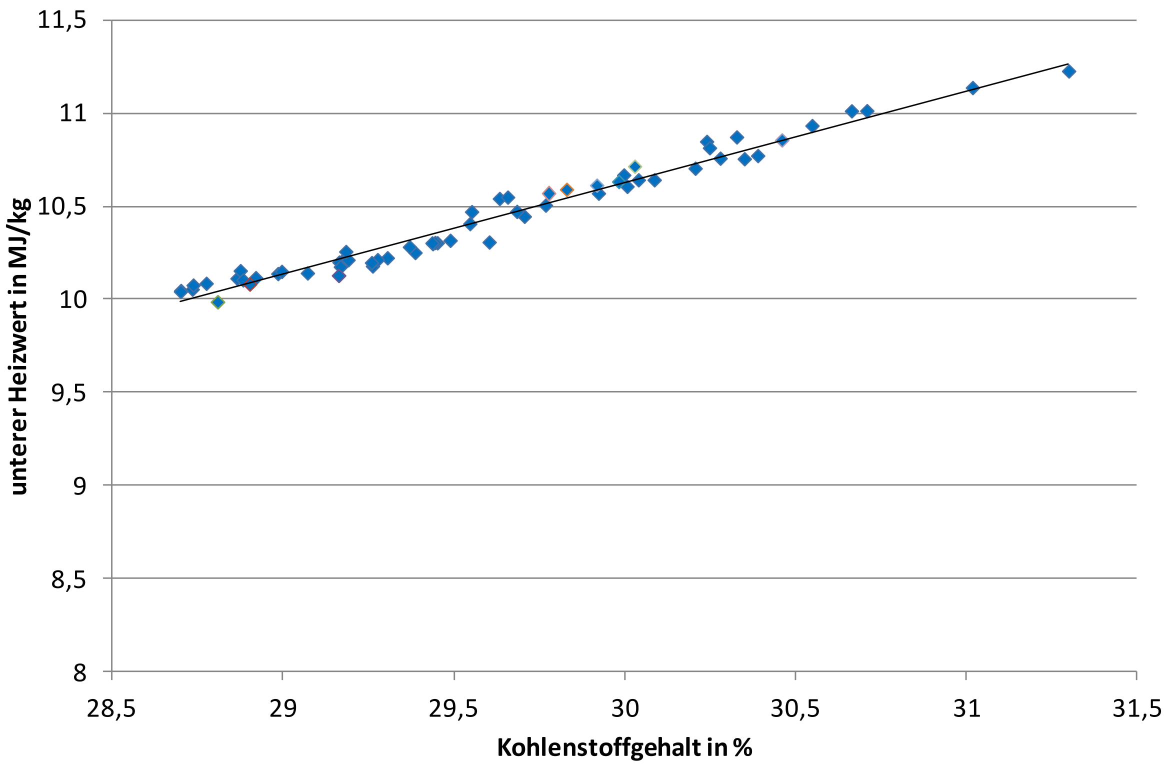

Figure 84: Relationship between carbon content and net calorific values, illustrated with the example of crude-lignite quality [x axis = Carbon content, in %; y axis = Lower net calorific value, in MJ/kg]

The variances in sulphur content are larger in lignite than they are in hard coal. Since sulphur content has a noticeable effect on net calorific value and, thus, on the relationship between carbon content and net calorific value, lignite has to be evaluated mining-district-specifically. As Figure 84 shows, there is a clear correlation between net calorific value and carbon content. Consequently, for each relevant year the carbon content, and the energy-related CO_2 emission factor, can be calculated, via a resulting formula, from the net calorific value as known for that year. This makes it possible to recalculate the figures back through 1990 – and thus to form a consistent time series. Some uncertainties do remain, however, since it is likely that a number of small mines were in operation in 1990 that produced coal with other sulphur-content levels. That supposition can no longer be checked, however. Hardly any carbon analyses were carried out in 1990, because carbon content was not an issue at that time. Only a few individual analyses were carried out, and their results are not necessarily representative. For example, only net-calorific-value data are available for lignite from the state of Hesse (Hessische Braunkohle), which was mined until 2003. For recalculation purposes, a mid-level sulphur content was assumed, a level between those found in the Mitteldeutsch ("central German") and Rhenish coalfields. That coal is of little relevance in terms of quantity, however. Between 1991 and 1992, the applicable emission factor changed sharply, because two power stations in that district went offline during that period, and they had been fired for some time with low-quality coal.

For raw-lignite inputs in district heating stations, a weighted emission factor is calculated from lignite inputs for the public electricity supply. For industry and the residential, institutional and commercial (small consumers) sectors, a weighted emission factor was calculated, from sales statistics of the DEBRIV Federal German association of lignite-producing companies and their affiliated organisations, that reflects the distribution of the relevant coalfields.

The emission factors for **lignite briquettes** were determined on the basis of emissions trading data for the period as of 2005. From those data, mining-district-specific averages, for each specific year, were formed. Then a weighted average was calculated from those averages, with the help of DEBRIV sales statistics. The emissions trading data cannot be used directly, since they do not completely reflect and cover the areas being reported on. The residential, institutional and commercial sectors do not take part in emissions trading. To ensure that the fuel-quality figures are the same, the ETS-based data evaluations were compared with our own analyses for briquettes in the residential sector. The two data sets show good agreement. While lignite briquettes are a standardized product, for which certain quality requirements apply, mining-district-specific differences still occur, in the form of carbon-content and sulphur-content variances in the raw lignite used. The recalculation back to 1990 proved to be considerably more complicated than the calculation for raw lignite. From the ETS data for the period 2005 – 2013, it was possible to calculate an average CO_2 emission factor only for Rhenish lignite briquettes. That factor can also be used for the years 1990 – 2004. In the new German Länder, a great many briquette factories were closed in the early 1990s. This considerably changed fuel quality levels in that region. No briquettes are now produced from central German (Mitteldeutsch) lignite. Consequently, no current relevant measurements are available. For this reason, we had to rely on archive data in this area. Data from analyses carried out by Mohry in 1986, and data from the 1986 "Jahresbericht der Kohleindustrie der DDR" ("annual report on the coal industry of the GDR") were available. It emerged that the carbon content previously assumed for central German (Mitteldeutsch) briquettes was too high, by a considerable amount. In calculation of the average values, care was taken to ensure that the resulting emission factors agreed with the net calorific values published by DEBRIV. As a result, it was possible to calculate an annual CO_2 emission factor for each coalfield. From those factors, it was then possible, with the help of DEBRIV sales statistics, to calculate weighted annual CO_2 emission factors.

Data on **lignite dust and fluidised-bed coal** are easier to obtain, since emissions trading data are available from all relevant coalfields. For the recalculations, average values from the years 2005, and 2008 – 2013, were used, depending on data quality. In an approach similar to that used for raw lignite and briquettes, a weighted CO_2 emission factor was calculated for lignite dust and fluidised-bed coal with the help of DEBRIV sales statistics.

Lignite coke is currently being produced in only one coalfield. In general, hearth furnace coke is used primarily for its properties as a material. Since fuel quality in this category fluctuates very little, an average was formed from the ETS data for the period 2008 – 2013 and then used for recalculations back through 1990. For the new German Länder, only one data source was available. That source consists of analyses carried out by the Ingenieurschule für Bergbau und Energetik "Ernst Thälmann" (the "Ernst Thälmann" school of engineering, specialising in mining and energy technology), located in Senftenberg. It seems plausible, however, that the coke studied in those analyses, in comparison to Rhenish coke, had a considerably lower carbon content and considerably higher ash and sulphur content. Consequently, the emission factor calculated for the new German Länder is lower.

The data set from the Ingenieursschule für Bergbau und Energetik "Ernst Thälmann" in Senftenberg also included analyses for **air-dried peat**. The net calorific value given agrees with the corresponding value used in the Energy Balance. The values for the **lignite tar oil** used in refineries in the new German Länder come from the same data source.

No data were available for the **lignite tar** used in the new German Länder. As an alternative, analysis data from the research report Vertrag Nr. (contract no.) 7220-EB/106 (DEBRIV 1980) were used. Lignite tar has not been used since 1991.

The ETS data can be used to generate CO_2 emission factors for **meta-lignite** for the period as of 2008. At present, only very small quantities of meta-lignite are used in Germany. To make it possible to calculate the applicable emission factors for the period back through 1990, the relevant carbon / net calorific value relationship was determined from the available ETS data. It was then possible, with the help of the net calorific values known from the DEBRIV lignite statistics, to produce a consistent time series.

18.7.3 Petroleum

Crude oil and **naphtha** are not used in combustion systems in Germany. For this reason, the emissions trading data do not include any carbon-content figures for these raw materials. In addition, no analysis values are available from other sources. For this reason, the default values from the 2006 Guidelines have been used. The relevant factors have been used only for the Reference Approach and for the transformation balance for refineries. Default values have also been used for **avgas** and **lubricants**.

For calculation of the CO_2 emission factors for **gasoline**, research report 502-1 of the German Society for Petroleum and Coal Science and Technology (DGMK), "Zusammensetzung von Ottokraftstoffen aus deutschen Raffinerien" ("composition of gasolines produced by German refineries") (DGMK 2002) was comprehensively evaluated. That study studied the components of the fuels involved in great detail. As a result, data are available on the average concentrations of 113 individual substances, and of 16 substance groups, in the categories regular gasoline, super (premium) and super plus (premium plus), for all German refineries. Via the carbon-content levels in the substances listed, and the pertinent concentrations, it was possible to calculate weighted carbon-content levels for each of the 3 grades of gasoline involved. This was because it was possible to calculate weight-based emission factors from carbon content. The following table presents the average values and fluctuation ranges ranges for the CO_2 factors:

Table 376: Composition of, and emission factors for, gasoline

		average CO_2 EF	Minimum	Maximum	Units
Regular gasoline		**3.183**	**3.160**	**3.206**	**t CO_2/ t**
Super (premium)		**3.185**	**3.152**	**3.211**	**t CO_2/ t**
Super plus (premium plus)		**3.141**	**3.102**	**3.176**	**t CO_2/ t**
With the following composition:					
Regular gasoline	Kerosenes	45.30	52.06	41.64	%
	Aromatic compounds	37.14	28.68	48.12	%
	Oxygen compounds	0.30	0.32	0.19	%
Super (premium)	Kerosenes	40.23	23.32	32.22	%
	Aromatic compounds	43.44	47.99	46.30	%
	Oxygen compounds	2.54	11.52	0.01	%
Super plus (premium plus)	Kerosenes	33.95	41.60	33.29	%
	Aromatic compounds	44.33	34.43	49.19	%
	Oxygen compounds	10.49	13.44	6.80	%

The naphthenes and olefins in the gasolines, while worthy of mention as additional components, have virtually no influence on CO_2 factors. In the case of regular gasoline, levels of aromatic compounds are the main factor that affects the size of CO_2 emission factors. On average, aromatic compounds tend to have higher carbon-content levels than kerosenes do. The levels of aromatic compounds found in a gasoline depend primarily on whether the refinery that produces the gasoline also produces basic chemical compounds. Where refineries do produce such compounds, efforts are made to make the highest possible fractions of aromatic compounds available for chemical production processes. The levels of aromatic compounds found in premium-grade gasolines fluctuate only very slightly. The CO_2 factors for such gasolines are determined primarily by the gasolines' content of oxygen compounds (MTBE). In the case of super plus (premium plus) grades, the levels of aromatic compounds and of oxygen compounds both play a role.

A weighted CO_2 emission factor has been calculated from the figures on annual sales of regular gasoline (Normalbenzin), premium (Super) and premium plus (Super Plus) (Official Mineral Oil Statistics). No figures for the new German Länder are available for the year 1990. For this reason, the breakdown by individual fuel qualities for the year 1991 has been applied to 1990. In the interest of consistency, an energy-related CO_2 emission factor has been calculated from the calculated weight-based emission factor and the lower net calorific value listed in the Energy Balance. So-calculated emission factors hardly fluctuate at all over the years concerned. The only year in which the emission factor changed more significantly was 2011, when the factor was unusually low. When the "E10" fuel was introduced (with a 10% biofuel fraction in premium grade fuel), greater quantities of Super Plus (premium plus) were sold.

The CO_2 emission factors for **light fuel oil, petroleum coke, heavy fuel oil** and **other petroleum products** have been calculated from emissions trading data. The relevant average values for the years 2005 – 2013 have been applied to the years back through 1990. It is difficult to draw a precise line between heavy fuel oil and other petroleum products. In keeping with Mineral Oil Statistics (Mineralölstatistik), "other petroleum products" have been defined as residual substances from refineries, and the pertinent emission factor has been calculated accordingly.

For **refinery gas**, a weight-based CO_2 emission factor has been calculated from the ETS data. Since the annual fluctuations for such gas are small, the same factor, formed from the average values for the years 2005 – 2013, has been used for all years. While the lower net calorific values given in the context of emissions trading show only slight annual fluctuations, the calorific values used in the Energy Balance vary significantly, in some cases, and show discrepancies with the ETS data. The refinery-gas quantities reported in the Energy Balance come from the Mineral Oil Statistics. Those values agree well with the ETS data. In the interest of consistency, the lower net calorific values used in the Energy Balance were chosen for inventory preparation. The pertinent emission factor has been adjusted accordingly.

For determination of the CO_2 emission factors for **LP gas**, first the applicable carbon content levels for butane and propane were calculated via molar masses. The pertinent fractions for the two components are published in the annual report of the German Liquid Petroleum Gas Association (Deutscher Verband Flüssiggas e.V.). The data through 1990 have also been provided by that association. Via the applicable fractions for the two components, a weighted emission factor years was calculated, and then that factor was divided by the lower net calorific value used in the Energy Balance. The LP gas emission factors published in the NIR apply only to energy-related consumption. The data for material-related use differ, since the relevant mixtures contain more butane than propane on average. Gas for energy-related use tends to contain more propane than butane.

18.7.4 Gases

Some gaseous fuels are allocated to the solid fuels category, in keeping with a) the IPCC fuel definitions and b) the Guidelines' emphasis on the fact that they originate in solid fuels or are produced from such fuels. This approach is taken for coke oven gas, town gas, blast furnace gas and basic oxygen furnace gas. The other relevant produced gases are allocated to the liquid fuels category, since those gases are produced primarily by the chemical industry, in non-energy-related consumption of naphtha and other petroleum products. These allocations play a necessary role in enabling the Reference Approach to achieve useful results.

For determination of CO_2 emission factors for **coke oven gas, blast furnace gas, basic oxygen furnace gas** and **petroleum gas**, emissions trading data are used. For the recalculations back through 1990, average values were calculated from the ETS data for the period 2005 – 2013 and then used for the years 1990 – 2004. In energy statistics, blast furnace gas and basic oxygen furnace gas are reported only as a gas mixture. For this reason, a weighted emission factor for such mixtures has been calculated from the individually determined emission factors for the two gases and from produced quantities of blast furnace gas and basic oxygen furnace gas. In all likelihood, the mixing ratios of such mixtures vary throughout the different specific areas in which the mixtures are used. Emissions trading data only partially cover combustion of blast furnace gas and basic oxygen furnace gas, but the calculation method used here ensures that the total emissions of such gases are still calculated correctly.

Until 1996, town gas was still used in Germany. In in the Energy Balance, it is combined with coke oven gas. The applicable fractions of **coke oven gas and town gas** cannot be determined on the usage side (the situation is similar to that for combustion of blast furnace gas and basic oxygen furnace gas). For this reason, here as a well a weighted emission factor is calculated – in this case from the produced quantities of coke oven gas and town gas. The values for **town gas** have been obtained from the firms of GASAG and DBI Gas- und Umwelttechnik GmbH Leipzig. Detailed analyses are available for the years 1989 through 1991. The different gases have been mixed so as to yield mixtures with fairly constant town-gas quality. DBI Gas- und Umwelttechnik GmbH Leipzig has also provided information regarding the mixing ratios in which the gas fractions are combined to produce summer-quality and winter-quality grades. The emission factors have been weighted accordingly. The figures for **fuel gas**, which is used exclusively in the new German Länder, have been obtained from a data set provided by the Ingenieurschule für Bergbau und Energetik "Ernst Thälmann" (the "Ernst Thälmann" school of engineering, specialising in mining and energy technology), located in Senftenberg. The term "fuel gas" has not been clearly defined. Since that gas has been used primarily in mine-mouth power plants, it may be assumed to be lignite-based. Such gases can vary widely in composition, however. Consequently, the applicable emission factors can also vary widely. They lie within the range 118.6 – 131 t CO_2/TJ. To ensure that the base-year emissions are not overestimated, a conservative approach is applied, and the lowest emission factor is used. The 1989 annual report for the energy sector (Energiewirtschaftlicher Jahresbericht 1989) gives a net calorific value of 5.3 MJ/Nm³ for "other gas", a figure that points to a higher emission factor. Since coke oven gas, town gas and fuel gas are reported in combined form in the Energy Balance, the net calorific values for those individual gases can no longer be determined.

Other produced gases are used primarily in the chemical industry. The category to which that term refers includes both a) gases with high calorific values and with large hydrogen fractions and b) flare gases with low calorific values and with large nitrogen fractions. The pertinent emission factor has been calculated from emissions trading data for the chemical industry. In the process, an average value for the years 2008 – 2013 was formed. Although the calorific-value figures given in energy statistics differ considerably from those used in emissions trading, the applicable cubic-metre quantities listed in the two contexts show good agreement. Consequently, an emission factor based on those natural units (cubic metres) was calculated for this category. In the interest of consistency, the net calorific value used in energy statistics is used for calculations for inventory preparation.

For **mine gas**, a methane content figure was calculated with the help of the methane-utilization data provided by the Gesamtverband Steinkohle (GVSt) hard-coal-mining association and the total methane quantities listed (in cubic metres) in the Energy Balance. A CO_2 emission factor was then calculated via the corresponding gas composition. Statistical differences result in some years, and thus calculations are carried out with the lowest methane-content figure, in the interest of applying a conservative approach.

Since the **natural gas** quantities recorded in the emissions trading context are not representative, and since default emission factors are often used in this category, the firm of DBI Gas- und Umwelttechnik GmbH Leipzig carried out its own analyses in the framework of the project "Messungen der Erdgasqualität an verschiedenen Stellen im Netz zur Ableitung bzw. Verifizierung von durchschnittlichen Emissionsfaktoren und Heizwerte von Erdgas" (2014; measurements of natural gas quality at various locations within the network, for purposes of derivation and verification of average emission factors and net calorific values for natural gas). In that effort, measurements were carried out at 32 locations throughout Germany. The measurement points were selected so as to ensure that all important imported gases and the country's own in-country production were taken into account. In addition, a mixture distributed in Germany was analysed. Alternative measuring sites were found for selected border handover points at which measures proved unfeasible. Within the relevant gas-quality ranges, the CO_2 emission factors fluctuate only very slightly. And the values fluctuate very little overall. In an approach similar to that used for other fuels, no sector-specific emission factors were determined for natural gas. As it is, the data do not allow determination of such factors. It thus seemed advisable, and more feasible, to determine weighted emission factors at the national level. They were calculated on the basis of the measurements carried out, of import flows and of the country's own production.

18.7.5 Waste and special fuels

For **waste**, a carbon content pursuant to VDI 3460 is assumed. Energy statistics serve as the data source for the calorific values. The data for **special fuels** were obtained from the project "Einsatz von Sekundärbrennstoffen" ("use of secondary fuels"; UBA 2005b, FKZ 204 42 203/02). These data still need to be reviewed, with the help of emissions trading data, and corrected as necessary. In general, it is difficult to compare data on fuels with relevant biomass fractions with ETS data, since the emission factors for such fuels do not always take account of the biomass fractions. What is more, the terms used in the ETS context are not always unambiguous. And since the net calorific values of special fuels vary considerably more strongly than those of conventional fuels do, net calorific values cannot be used for unambiguous identification of special fuels. All of these factors considerably complicate such comparisons. While for conventional fuels inter-sectoral emission factors are determined in most cases, for special fuels the factors have to be calculated sector-specifically.

For a few special fuels, emissions trading data have already been evaluated. This applies to **waste oil** and **waste plastics**. The relevant values are used in the carbon balance for the iron and steel industry. The emission factor for **waste tyres** has been calculated from ETS data from the year 2010.

18.7.6 Biomass fuels

The emission factors for the biomass fuels that are used as **substitute fuels** in industry have also been obtained via the project "Einsatz von Sekundärbrennstoffen" ("use of secondary fuels"; UBA 2005b, FKZ 204 42 203/02). The CO_2 emission factors for **wood** have been obtained from the research report "Effiziente Bereitstellung aktueller Emissionsdaten für die Luftreinhaltung" ("Efficient provision of current emissions data for purposes of air quality control"; STRUSCHKA 2008).

The process for calculation of the CO_2 emission factors for **biogas, landfill gas** and **sewage gas** began with evaluation of relevant net calorific values from energy statistics. Averages of those calorific values were then calculated for each category from the values for the years 2009 – 2011. Then, corresponding methane quantities were determined from each such average calorific value. Apart from methane, these gases consist mainly of carbon dioxide and a small nitrogen fraction. As a result, the net calorific value is determined via the methane content. The biogases also contain other hydrocarbons, in fractions totalling about 1 %. A CO_2 emission factor was then calculated via this known gas composition.

The emission factor for **bioethanol** was calculated on the basis of the number of carbon atoms, and of the molar mass, of ethanol. The relevant net calorific value is published by the Bundesverband der Deutschen Bioethanolwirtschaft German bioethanol industry association. For **bodiesel**, we did not carry out any analyses of our own. For this reason, the default emission factor given in the IPCC 2006 Guidelines has been used.

18.7.7 List of carbon dioxide emission factors derived for energy & industrial processes

The following tables provide an overview of the carbon dioxide emission factors used in the inventory.

Table 377: CO_2 emission factors derived for emissions reporting for the period as of 1990; energy

Fuel-based emission factors	Units	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Coal																									
Hard coal																									
Raw hard coal (power stations, industry)	t CO2/TJ	93.1	93.1	93.2	93.2	93.2	93.1	93.2	93.4	93.4	93.4	93.5	93.8	93.8	93.9	93.9	93.9	93.9	93.8	94.3	94.1	94.0	94.2	93.7	93.4
Hard-coal briquettes	t CO2/TJ	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9
Hard-coal coke (not including that for the iron & steel industry)	t CO2/TJ	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1
Hard-coal coke for the iron & steel industry	t CO2/ t	3.29	3.29	3.28	3.27	3.27	3.26	3.25	3.25	3.24	3.23	3.23	3.22	3.21	3.21	3.20	3.19	3.18	3.16	3.17	3.17	3.18	3.17	3.17	3.20
Anthracite (heat market for households, commerce, trade, services)	t CO2/TJ	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6
Ballast hard coal, *old German Länder*	t CO2/TJ	95.2	95.2	95.2	95.2	95.2																			
Coking coal, *Germany*	t CO2/ t	2.96	2.96	2.95	2.94	2.94	2.93	2.93	2.92	2.91	2.91	2.90	2.89	2.89	2.88	2.88	2.87	2.86	2.86	2.85	2.85	2.86	2.85	2.86	2.85
Hard coal for the iron & steel industry	t CO2/ t	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.95	2.99	2.96	2.91	2.86	2.89	2.89	2.91	2.96
Other hard-coal products	t CO2/ t	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.27	3.29	3.29	3.30	3.30	3.32
Hard-coal tar	t CO2/ t	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.28	3.28	3.28	3.24	3.26	3.27	3.27	3.28	3.31
Benzene	t CO2/ t	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38
Lignite																									
Raw lignite																									
Public district heating stations, *Germany*	t CO2/TJ						111.7	111.5	111.5	111.3	111.1	110.8	110.6	110.9	110.7	110.7	111.1	111.2	111.3	111.5	111.4	110.7	110.7	111.0	110.7
Old German Länder	*t CO2/TJ*	113.8	113.5	113.5	113.6	113.4																			
New German Länder	*t CO2/TJ*	110.0	110.0	110.2	110.4	110.3																			
Industry, commerce, trade, services, *Germany*	t CO2/TJ						106.0	108.6	111.2	111.1	110.8	109.8	108.5	108.9	109.1	109.2	108.2	107.3	107.4	106.5	106.1	106.3	106.0	105.0	105.1
Old German Länder	*t CO2/TJ*	114.7	114.5	113.7	113.8	113.5																			
New German Länder	*t CO2/TJ*	107.7	107.2	107.2	107.5	106.5																			
Public power stations; coalfield:																									
Rheinland	t CO2/TJ	114.8	114.5	114.5	114.6	114.3	113.9	113.8	113.8	113.5	113.3	113.1	112.7	112.9	112.7	112.6	113.2	113.5	113.5	113.8	113.6	113.3	113.3	113.2	113.0
Helmstedt	t CO2/TJ	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	95.2	97.3	96.7	101.7	97.9	103.3
Hesse	t CO2/TJ	112.2	114.7	103.7	102.4	103.0	103.2	103.7	102.4	102.7	103.4	103.5	104.0	103.9	102.5	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Lausitz	t CO2/TJ	111.2	111.2	111.3	111.3	111.4	111.3	111.2	111.3	111.3	111.4	111.5	111.5	111.4	111.4	111.3	111.2	111.3	111.3	112.2	112.0	110.6	109.9	111.0	110.3
Mitteldeutschland	t CO2/TJ	105.7	105.2	104.9	105.2	103.8	103.9	103.7	103.7	103.7	103.4	102.9	103.4	103.6	103.7	103.7	104.0	103.9	103.5	103.4	103.3	103.4	103.4	102.8	102.9
Lignite briquettes, *Germany*	t CO2/TJ						98.3	98.5	98.5	98.7	98.9	99.0	99.1	99.1	99.0	99.3	99.3	99.0	99.6	99.8	99.4	99.0	99.3	99.3	99.1
Old German Länder	*t CO2/TJ*	99.5	99.5	99.5	99.5	99.5																			
New German Länder	*t CO2/TJ*	96.6	96.1	95.5	95.9	96.9																			
Lignite tar, *New German Länder*	t CO2/TJ	82.9	82.9	82.9	82.9	82.9																			
Lignite tar oil, *New German Länder*		78.6	78.6	78.6	78.6	78.6																			
Lignite dust and fluidised bed coal, *Germany*	t CO2/TJ						97.6	97.8	97.9	97.9	98.0	98.1	98.1	98.0	98.0	98.0	98.1	98.1	97.9	98.0	97.8	98.0	98.1	98.0	98.0
Old German Länder	*t CO2/TJ*	98.3	98.3	98.3	98.3	98.3																			
New German Länder	*t CO2/TJ*	96.1	95.5	95.6	95.9	95.8																			
Lignite coke, *Germany*	t CO2/TJ						109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6
Old German Länder	*t CO2/TJ*	109.6	109.6	109.6	109.6	109.6																			
New German Länder	*t CO2/TJ*	100.2	100.2	100.2																					
Peat, *old German Länder, Germany*		101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8	NO	NO	NO	NO	NO	NO	NO
Meta-lignite ("hard lignite")	t CO2/TJ	96.4	96.3	96.4	96.4	96.3	96.4	96.4	96.4	96.4	96.3	96.5	96.4	96.9	97.7	NO	NO	96.6	95.7	96.7	95.5	94.9	94.8	94.9	94.2

Fuel-based emission factors	Units	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Petroleum																									
Crude oil	t CO2/TJ	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3
Gasoline	t CO2/TJ	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.0	73.1	73.1
Naphtha, *Germany*	t CO2/TJ						73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3
Old German Länder	*t CO2/TJ*	73.3	73.3	73.3	73.3	73.3																			
New German Länder	*t CO2/TJ*	73.3	73.3	73.3	73.3	73.3																			
Kerosene	t CO2/TJ	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3
Avgas	t CO2/TJ	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
Diesel, *Germany*	t CO2/TJ						74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0
Old German Länder	*t CO2/TJ*	74.0	74.0	74.0	74.0	74.0																			
New German Länder	*t CO2/TJ*	73.0	74.0	74.0	74.0	74.0																			
Light fuel oil, *Germany*	t CO2/TJ						74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0
Old German Länder	*t CO2/TJ*	74.0	74.0	74.0	74.0	74.0																			
New German Länder	*t CO2/TJ*	74.0	74.0	74.0	74.0	74.0																			
Heavy fuel oil	t CO2/TJ	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.6	79.7	79.8	80.1	79.0	79.7	79.9	80.1	80.0
Petroleum	t CO2/TJ	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	
Petroleum coke (not including coke burn-off in catalyst regeneration)	t CO2/TJ	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	95.0	94.2	94.6	95.4	94.7	95.1
LP gas, *Germany (energy-relatec consumption)*	t CO2/TJ						65.3	65.2	65.2	65.2	64.0	64.4	64.5	64.4	65.0	65.3	65.3	65.4	66.6	65.2	65.3	65.3	65.4	65.4	65.4
Old German Länder	*t CO2/TJ*	65.6	65.6	65.5	65.4	65.3																			
New German Länder	*t CO2/TJ*	65.6	65.6	65.5	65.4	65.3																			
Refinery gas, *Germany*	t CO2/TJ						56.9	56.2	56.8	56.3	60.9	56.7	62.0	58.1	57.0	57.6	57.0	57.1	57.6	57.9	62.2	65.4	61.3	62.3	62.3
Old German Länder	*t CO2/TJ*	*54.6*	*54.6*	*57.8*	*57.1*	*58.5*																			
New German Länder	*t CO2/TJ*	*54.6*	*54.6*	*54.6*	*57.1*	*58.5*																			
Other petroleum products, *Germany*	t CO2/TJ						82.1	82.1	82.1	82.1	82.1	82.1	82.1	82.1	82.1	82.1	82.1	82.1	82.1	82.1	82.1	82.1	82.1	82.1	82.1
Old German Länder	*t CO2/TJ*	82.1	82.1	82.1	82.1	82.1																			
New German Länder	*t CO2/TJ*	82.1	82.1	82.1	82.1	82.1																			
Lubricants	t CO2/TJ	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3
Gases																									
Coke oven gas, *Deutschland*	t CO2/TJ						41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0	40.7	41.1	40.6	40.9	41.1	40.3	41.6	41.2	41.8
Old German Länder	*t CO2/TJ*	41.0	41.0	41.0	41.0	41.0																			
New German Länder	*t CO2/TJ*	43.6	43.6	43.6	43.6	43.6																			
Coke oven gas and town gas, *Germany*	*t CO2/TJ*						42.6	42.0																	
Old German Länder	*t CO2/TJ*	43.2	43.7	43.8	44.0	43.3																			
New German Länder	*t CO2/TJ*	58.3	59.9	61.4	61.6	62.4																			
Blast furnace gas and basic oxygen furnace gas, *Germany*	t CO2/TJ						257.1	259.0	258.9	258.7	258.6	258.7	258.8	258.6	258.7	258.7	252.9	256.6	249.4	257.5	265.9	259.7	264.7	263.5	259.5
Old German Länder	*t CO2/TJ*	264.6	264.6	264.6	255.3	257.1																			
New German Länder	*t CO2/TJ*	264.6	264.6	264.6	258.5	258.2																			
Fuel gas, *New German Länder*	t CO2/TJ	118.4	118.4	118.4	118.4	118.4																			
Other produced gases, *Germany*	t CO2/1000 m³	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77
Natural gases																									
Natural gas, *Germany*	t CO2/TJ						55.8	55.8	55.8	55.8	55.8	55.8	55.9	55.9	55.9	55.9	55.9	55.9	55.9	55.9	55.9	55.9	55.9	55.9	55.9
Old German Länder	*t CO2/TJ*	55.7	55.8	55.8	55.8	55.8																			
New German Länder	*t CO2/TJ*	55.5	55.5	55.4	55.4	55.4																			

Fuel-based emission factors	Units	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Petroleum gas	t CO2/TJ	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9
Pit gas	t CO2/TJ	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1
Waste																									
Household waste / municipal waste	t CO2/TJ	109.6	107.0	104.6	100.1	98.0	96.9	95.8	94.7	93.6	92.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5
Industrial waste, *Germany*	t CO2/TJ						71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1
Old German Länder [2)]	*t CO2/TJ*	73.9	73.9	74.0	74.1	74.3																			
New German Länder [2)]	*t CO2/TJ*	74.9	74.8	74.7	74.6	74.6																			
Special waste, *Germany*	t CO2/TJ						83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0
Special fuels [1)]																									
Used oil	t CO2/t	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	3.11	2.91	3.02	2.93	2.97	2.96	2.97	2.98	2.95
Waste plastics	t CO2/t						2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.64	2.70	2.70	2.70	2.62	2.76	2.71	2.67	2.74
Waste tyres	t CO2/TJ	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4
Bleaching clay	t CO2/TJ	NO	NO	NO	NO	NO	82.3	82.3	82.3	82.3	82.3	82.3	82.3	82.3	82.3	82.3	82.3	82.3	82.3	82.3	82.3	82.3	82.3	82.3	82.3
Commercial waste – plastic	t CO2/TJ	NO	NO	NO	NO	NO	83.1	83.1	83.1	83.1	83.1	83.1	83.1	83.1	83.1	83.1	83.1	83.1	83.1	83.1	83.1	83.1	83.1	83.1	83.1
Commercial waste – paper	t CO2/TJ	NO	NO	NO	NO	NO	64.9	64.9	64.9	64.9	64.9	64.9	64.9	64.9	64.9	64.9	64.9	64.9	64.9	64.9	64.9	64.9	64.9	64.9	64.9
Commercial waste – other	t CO2/TJ	NO	NO	NO	NO	NO	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1
Commercial waste – packaging	t CO2/TJ	NO	NO	NO	NO	NO	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9
Sewage sludge	t CO2/TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	95.1	95.1	95.1	95.1	95.1	95.1	95.1	95.1	95.1	95.1	95.1
Solvents (waste)	t CO2/TJ	NO	NO	NO	NO	NO	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1
Oil sludge	t CO2/TJ	NO	NO	NO	NO	NO	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0
Paper-industry residues	t CO2/TJ	86.2	86.2	86.2	86.2	86.2	86.2	86.2	86.2	86.2	86.2	86.2	86.2	86.2	86.2	86.2	86.2	86.2	86.2	86.2	86.2	86.2	86.2	86.2	86.2
Processed municipal waste	t CO2/TJ	59.8	59.8	59.8	59.8	59.8	59.8	59.8	59.8	59.8	59.8	59.8	59.8	59.8	59.8	59.8	59.8	59.8	59.8	59.8	59.8	59.8	59.8	59.8	59.8
Carpet waste	t CO2/TJ	NO	NO	NO	NO	NO	80.4	80.4	80.4	80.4	80.4	80.4	80.4	80.4	80.4	80.4	80.4	80.4	80.4	80.4	80.4	80.4	80.4	80.4	80.4
Textile waste	t CO2/TJ	NO	NO	NO	NO	NO	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3

Fuel-based emission factors	Units	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Biomass fuels [3]																									
Spent liquors from pulp production	t CO2/TJ	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0
Fibre/de-inking residues	t CO2/TJ	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9
Firewood, untreated	t CO2/TJ	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1
Waste wood, wood scraps (industry)	t CO2/TJ	NO	NO	NO	NO	NO	95.1	95.1	95.1	95.1	95.1	95.1	95.1	95.1	95.1	95.1	95.1	95.1	95.1	95.1	95.1	95.1	95.1	95.1	95.1
Waste wood, wood scraps (commercial/institutional)	t CO2/TJ	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4
Bark	t CO2/TJ	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6
Animal meals and fats	t CO2/TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	74.9	74.9	74.9	74.9	74.9	74.9	74.9	74.9	74.9	74.9	74.9	74.9	74.9
Animal fat	t CO2/TJ	71.4	71.4	71.4	71.4	71.4	71.4	71.4	71.4	71.4	71.4	71.4	71.4	71.4	71.4	71.4	71.4	71.4	71.4	71.4	71.4	71.4	71.4	71.4	71.4
Biogas	t CO2/TJ	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6
Landfill gas	t CO2/TJ	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4
Sewage gas	t CO2/TJ	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9
Bioethanol	t CO2/TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6
Biodiesel [4]	t CO2/TJ	NO	NO	NO	NO	NO	70.8	70.8	70.8	70.8	70.8	70.8	70.8	70.8	70.8	70.8	70.8	70.8	70.8	70.8	70.8	70.8	70.8	70.8	70.8
Other factors, units [kg/t]																									
Flue-gas desulphurisation		440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0

1) Designations of fuels as defined for the inventory data can diverge from other standards, and they are listed as such, and given EF as such, only in the inventory.

2) Annual changes in EF as a result of varying fractions for combustion systems and plants' own systems

3) 1990 through 1994 – for each year, separately for old German Länder / new German Länder

4) Listed for selected fuels; calculated CO_2 emissions are reported only as memo items, and do not enter into the total inventory quantities; biomass fractions from special fuels (see above) are not listed separately, because their CO_2 EF are not differentiated.

5) Default values

Remark: The information and FAQ provided by the German Emissions Trading Authority (DEHSt) must be taken into account in any use of substance data from the NIR in the context of the ETS.

Table 378: Emission factors for CO_2 as of 1990, as derived for emissions reporting: industrial processes

Industrial processes [kg CO_2/ t (raw material or product)]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
2.A.1 Production of cement clinkers	530.00	530.00	530.00	530.00	530.00	530.00	530.00	530.00	530.00	530.00	530.00	530.00	530.00	530.00	530.00
2.A.2 Production of burnt lime	746.00	746.00	746.00	746.00	746.00	746.00	746.00	746.00	746.00	746.00	746.00	746.00	746.00	746.00	746.00
2.A.2 Production of dolomite lime	867.00	867.00	867.00	867.00	867.00	867.00	867.00	867.00	867.00	867.00	867.00	867.00	867.00	867.00	867.00
2.A.3 Production of container glass	193.00	193.00	193.00	193.00	193.00	193.00	193.00	193.00	193.00	193.00	193.00	193.00	193.00	193.00	193.00
2.A.3 Production of flat glass	208.00	208.00	208.00	208.00	208.00	208.00	208.00	208.00	208.00	208.00	208.00	208.00	208.00	208.00	208.00
2.A.3 Production of household and table glassware	120.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00
2.A.3 Production of special glass (mix)	113.00	113.00	113.00	113.00	113.00	113.00	113.00	113.00	113.00	113.00	113.00	113.00	113.00	113.00	113.00
2.A.3 Production of glass fibres (mix)	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00
2.A.3 Production of rock wool (mix)	299.00	299.00	299.00	299.00	299.00	299.00	299.00	299.00	299.00	299.00	299.00	299.00	299.00	299.00	299.00
2.A.3 Production of glass (mix not differentiated for new German Länder)	174.00	174.00	174.00	174.00	174.00	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.A.3 Production of glass (mix for Germany, including cullet inputs)	119.00	114.00	112.00	110.00	96.00	116.00	113.00	113.00	110.00	110.00	113.00	116.00	113.00	109.00	112.00
2.A.4.a Production of masonry bricks	29.10	29.10	29.10	29.10	29.10	29.10	29.10	29.10	29.10	29.10	29.10	29.10	29.10	29.10	29.10
2.A.4.a Production of roof tiles	28.60	28.60	28.60	28.60	28.60	28.60	28.60	28.60	28.60	28.60	28.60	28.60	28.60	28.60	28.60
2.A.4.b Use of soda ash	415.00	415.00	415.00	415.00	415.00	415.00	415.00	415.00	415.00	415.00	415.00	415.00	415.00	415.00	415.00
2.B.1 Production of ammonia	2,405.10	2,454.20	2,470.30	2,469.70	2,441.40	2,410.30	2,349.30	2,411.70	2,366.60	2,419.30	2,340.40	2,347.80	2,394.10	2,381.50	2,421.90
2.B.5 Production of calcium carbide	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
2.B.7 Production of soda ash	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
2.B.8 Petrochemicals	14.89	14.89	14.89	14.89	14.89	14.89	14.89	14.89	14.89	14.89	14.89	14.89	14.89	14.89	14.89
2.B.8.f Production of carbon black	0.00196	0.00196	0.00196	0.00196	0.00196	0.00196	0.00196	0.00196	0.00196	0.00196	0.00196	0.00196	0.00196	0.00196	0.00196
2.C.1 Production of electric steel	8.50	8.00	7.50	7.374	7.374	7.374	7.374	7.374	7.374	7.374	7.374	7.374	7.374	7.374	7.374
2.C.1 Production of oxygen steel; limestone input	440.00	440.00	440.00	440.00	440.00	440.00	440.00	440.00	440.00	440.00	440.00	440.00	440.00	440.00	440.00
2.C.2 Ferroalloys production	1500.00	1222.00	944.00	527.00	249.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
2.C.2 Ferroalloys production (new German Länder)	1500.00	1500.00	1500.00	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.C.3 Production of foundry aluminium	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00
2.C.5 Production of refined lead (D)						371.00	220.00	220.00	220.00	220.00	220.00	220.00	220.00	220.00	220.00
2.C.5 Production of refined lead (old German Länder)	434.00	368.50	368.50	368.50	368.50										
2.C.5 Production of refined lead (new German Länder)	200.00	200.00	200.00	200.00	200.00										
2.C.6 Zinc production: foundry and resmelted zinc (D)	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00

Industrial processes [kg CO_2/ t (raw material or product)]	2005	2006	2007	2008	2009	2010	2011	2012	2013
2.A.1 Production of cement clinkers	530.00	530.00	530.00	530.00	530.00	530.00	530.00	530.00	530.00
2.A.2 Production of burnt lime	746.00	746.00	746.00	746.00	746.00	746.00	746.00	746.00	746.00
2.A.2 Production of dolomite lime	867.00	867.00	867.00	867.00	867.00	867.00	867.00	867.00	867.00
2.A.3 Production of container glass	193.00	193.00	193.00	193.00	193.00	193.00	193.00	193.00	193.00
2.A.3 Production of flat glass	208.00	208.00	208.00	208.00	208.00	208.00	208.00	208.00	208.00
2.A.3 Production of household and table glassware	120.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00
2.A.3 Production of special glass (mix)	113.00	113.00	113.00	113.00	113.00	113.00	113.00	113.00	113.00
2.A.3 Production of glass fibres (mix)	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00
2.A.3 Production of rock wool (mix)	299.00	299.00	299.00	299.00	299.00	299.00	299.00	299.00	299.00
2.A.3 Production of glass (mix not differentiated for new German Länder)	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.A.3 Production of glass (mix for Germany, including cullet inputs)	116.00	116.00	110.00	110.00	110.00	116.00	114.00	114.00	118.00
2.A.4.a Production of masonry bricks	29.10	29.10	29.10	29.10	29.10	29.10	29.10	29.10	29.10
2.A.4.a Production of roof tiles	28.60	28.60	28.60	28.60	28.60	28.60	28.60	28.60	28.60
2.A.4.b Use of soda ash	415.00	415.00	415.00	415.00	415.00	415.00	415.00	415.00	415.00
2.B.1 Production of ammonia	2,372.80	2,310.40	2,363.90	2,383.50	2,492.10	2,377.50	2,350.70	2,421.50	2,353.50
2.B.5 Production of calcium carbide	C	C	C	C	C	C	C	C	C
2.B.7 Production of soda ash	C	C	C	C	C	C	C	C	C
2.B.8 Petrochemicals	14.89	14.89	14.89	14.89	14.89	14.89	14.89	14.89	14.89
2.B.8.f Production of carbon black	0.00196	0.00196	0.00196	0.00196	0.00196	0.00196	0.00196	0.00196	0.00196
2.C.1 Production of electric steel	7.374	7.374	7.374	7.374	7.374	7.374	7.374	7.374	7.374
2.C.1 Production of oxygen steel; limestone input	440.00	440.00	440.00	440.00	440.00	440.00	440.00	440.00	440.00
2.C.2 Ferroalloys production	110.00	110.00	110.00	110.00	110.00	111.00	111.00	111.00	111.00
2.C.2 Ferroalloys production (new German Länder)	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.C.3 Production of foundry aluminium	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00
2.C.5 Production of refined lead (D)	220.00	220.00	220.00	220.00	220.00	220.00	220.00	220.00	220.00
2.C.5 Production of refined lead (old German Länder)									
2.C.5 Production of refined lead (new German Länder)									
2.C.6 Zinc production: foundry and resmelted zinc (D)	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00

C Confidential data

NO Not occuring

Remark: The information and FAQ provided by the German Emissions Trading Authority (DEHSt) must be taken into account in any use of substance data from the NIR in the context of the ETS.

18.8 Analysis of CO_2 emissions from non-energy-related use of fuels

The great majority of the coal, oil and gas that Germany uses is used for energy-related purposes. The remainder of the coal, oil and gas is used as feedstock for production processes. This consumption enters into the balance as "non-energy use" (NEU).

In the German Energy Balance, this consumption is listed separately, in line 43. The chemical industry is the leading user of fossil fuels for non-energy-related purposes. In that industry, fossil fuels are used in crackers, reforming processes and production of synthetic gases. In crackers and reforming, the most important products resulting from such processes are ethylene, propylene, 1,3-butadiene, benzene, toluene and xylene; in production of synthetic gases, the most important such products are ammonia and methanol. Bitumen, lubricants and paraffin waxes are produced in refineries. Bitumen is used in a range of applications, including road surfaces and bitumen sheeting for roofs. Lubricants are used in road vehicles and machines (inter alia). Other use consists of production of graphite electrodes.

Table 379 (see below) presents a comparison of a) the consumption listed in Energy Balance line 43 and b) emissions, as reported in the inventory, of CO_2 and NMVOC from use of fossil fuels in non-energy-related applications. In the interest of complete accounting, the carbon quantities stored in the relevant fossil fuel products were taken into account. The correlation between material-related applications and products and the various relevant fuels is oriented to Table 1.3 from Volume 3 of the 2006 IPCC GL, and is based on information provided by relevant associations, producers and experts. In some cases, we had to make our own estimates of the applicable correlation with individual fuels.

The produced quantities of the listed products have been obtained from data reported by the Federal Statistical Office and by the Federal Office of Economics and Export Control (BAFA) and have been converted into CO_2 equivalents. For methanol, ethylene, propylene, 1,3-butadiene, benzene, toluene and xylene, the conversions were carried out via the molar masses of the relevant products and the molar mass of CO_2. The pertinent CO_2 equivalent emissions were split among the three feedstocks used in Germany (naphta, LP gas and other petroleum products), in keeping with (internal) data provided by associations. Below, conversion into CO_2 equivalents is illustrated with the example of ethylene (C_2H_4):

M (CO_2) = 44 g/mol
M (C_2H_4) = 28
CO_2 equivalent = AR *2*44/28.

In the case of carbon black, the product is assumed to consist of pure carbon. That carbon was also converted into CO_2 equivalents.

The production quantities for bitumen, lubricants and paraffin waxes have been taken from the official Mineral Oil Statistics, and they have been converted into CO_2 equivalents with the help of the following IPCC standard values (Table 1.2 and Table 1.4 from Vol. 2 of the 2006 IPCC GL).

	EF t CO_2/TJ	Lower net calorific value TJ/kt
Bitumen	80.6	40.2
Paraffin wax	73.3	40.2
Lubricating oil	73.3	40.2

The resulting CO_2 equivalents are in keeping with those of the Reference Approach.

For the year 2013, the sum of the carbon from the pertinent emissions and of the carbon stored in products amounts to 94 % of the non-energy-related consumption given in line 43 of the Energy Balance. Consequently, the relevant material-related use can clearly be shown to include the quantities listed in the Energy Balance as non-energy-related consumption. No gaps in determination of non-energy-related CO_2 emissions are apparent in the inventory.

Table 379: Verification of the completeness of reported CO_2 from non-energy-related use of fossil fuels

Year	2010	Units	Coal						Petroleum									Gas	
			Hard coal	**Hard-coal coke**	**Other hard-coal products**	**Lignite**	**Other lignite products**	**Total, solid fuels**	**Raw benzene (naphtha)**	**Diesel fuel**	**Heating oil, light**	**Heating oil, heavy**	**Petrol coke**	**LP gas**	**Refinery gas**	**Other petroleum products**	**Total, liquid fuels**	**Natural gas**	**Total, gas**
A: Listed NEU quantity (Energy Balance line 43)		TJ	1 703	2 521	4 411	300	15 826		469 333	8	39 337	157 909	7 341	60 537	19 302	145 059		110 434	
B: Carbon content		kg C/GJ	26.8	29.2	26.8	27.6	27.6		20.0	20.2	20.2	21.1	26.6	17.2	15.7	20.0		15.3	
C: Total input as feedstock / non-energy use		Gg C	45.6	73.6	118.2	8.3	436.8	682.5	9,386.7	0.2	794.6	3,331.9	195.3	1,041.2	303.0	2,901.2	17,954.0	1,689.6	1,689.6
D: Total input as feedstock / non-energy use		**Gg CO_2**	**167.3**	**269.9**	**433.5**	**30.4**	**1,601.6**	**2,502.7**	**34,417.8**	**0.6**	**2,913.6**	**12,216.9**	**716.0**	**3,817.9**	**1,111.2**	**10,637.7**	**65,831.5**	**6,195.3**	**6,195.3**
E: Implied oxidised carbon fraction		**%**	**0%**	**206%**	**0%**	**0%**	**0%**	**22%**	**96%**	**0%**	**0%**	**56%**	**2%**	**88%**	**0%**	**185%**	**95%**	**84%**	**84%**
	Activity data [Gg]	**Emissions (Gg CO_2)**			**Activity data + emissions (C in Gg CO_2)**								**Activity data + emissions (C in Gg CO_2)**						
F: Total reported fossil IPPU CO_2		**6,709**		**557**				**557**	**32,915**		**0**	**6,796**	**17**	**3,365**		**19,653**	**62,747**	**5,209**	**5,209**
2 Industrial processes		**6,709**						**557**				**6,796**	**17**	**3,365**		**4,812**	**47,906**	**5,209**	**5,209**
2B: Chemical industry		**6,152**						**0**	**32,915**		**0**	**6,796**	**17**	**3,365**		**4,812**	**47,906**	**5,209**	**5,209**
2B1: Ammonia production	3,128	4,076						0				2,717					2,717	1,359	1,359
2B1: Ammonia production: CO_2 for further use	3,361											3,361					3,361		
2B5: Carbide production	C	17						0					17				17		0
2B5: Other																			
Methanol CH3OH	*C*	*718*										*718*					*718*		
Ethylene C2H4	*5,063*								*12,747*					*1,303*		*1,863*	*15,914*		
Propylene C3H6	*3,905*								*9,830*					*1,005*		*1,437*	*12,272*		
1,3-butadiene C4H6	*1,151*								*3,004*					*307*		*439*	*3,751*		
Benzene C6H6	*1,874*								*5,081*					*520*		*743*	*6,344*		
Toluene C7H8	*662*								*1,776*					*182*		*260*	*2,218*		
Xylene C8H10	*179*								*476*					*49*		*70*	*595*		
Carbon black	*684*	*1,341*															*0*	*3,850*	*3,850*

Year	2010	Units	Coal Hard coal	Hard-coal coke	Other hard-coal products	Lignite	Other lignite products	Total, solid fuels	Petroleum Raw benzene (naphtha)	Diesel fuel	Heating oil, light	Heating oil, heavy	Petrol coke	LP gas	Refinery gas	Other petroleum products	Total, liquid fuels	Gas Natural gas	Total, gas
	Activity data [Gg]	Emissions (Gg CO_2)	Activity data + emissions (C in Gg CO_2)						Activity data + emissions (C in Gg CO_2)										
2C: Metal industry		**557**		**557**				**557**											
2C1: Iron and steel production (1)	IE	IE						0									0		0
2C2: Production of ferroalloys	55	6		6				6									0		0
2C3: Primary aluminium production	403	551		551				551									0		0
2C5: Other								0									0		0
Lead production	*NE*	*NE*						*0*									*0*		*0*
Zinc production	*NE*	*NE*						*0*									*0*		*0*
3: Solvents and other product use (2)	**IE**	**IE**						**0**	**IE**								**0**		**0**
Exceptions reported elsewhere																			
1A Combustion of fuels		**0**														**14,841**	**14,841**		
1A1b: Petroleum refineries																			0
Lubricants	1173							0								3,456	3,456		0
Waxes, paraffins, vaseline, etc.	123															362	362		
Bitumen	3,402															11,023	11,023		
1A3 Lubricants in road transports (3)	IE	IE						0								IE	0		0

(1) Since coke inputs in the iron and steel industry are not included in the Energy Balance, the relevant CO_2 emissions are not included here.

(2) Since over 90 % of solvents from basic chemicals are produced in steam crackers, it is assumed that carbon emitted from NMVOCs comes from products of such crackers.

(3) Use of lubricants is already covered by the total quantity of produced lubricants.

19 ANNEX 3: OTHER DETAILED METHODOLOGICAL DESCRIPTIONS FOR INDIVIDUAL SOURCE OR SINK CATEGORIES, INCLUDING KP-LULUCF ACTIVITIES

19.1 Other detailed methodological descriptions for the source category "Energy" (1)

19.1.1 Revision of the activity rates for stationary combustion systems of the new German Länder for the year 1990 and for subsequent years (1.A.1 and 1.A.2)

Problems with the GDR's official statistics in 1990, the year of German reunification, along with the creation of a standardised system of official statistics for all of Germany, had a noticeable effect on the quality of figures, as reported in past inventories, for activity rates of stationary combustion systems of the new German Länder for the year 1990 (and for subsequent years). For this reason, these figures have been revised. This work was carried out by the Institute for Energy and Environment (Institut für Energetik und Umwelt gGmbH; IE gGmbH). In work package 1 of the research project "Base year and update" ("Basisjahr und Aktualisierung"; UBA, 2005c: FKZ 20541115), "the activity rates for stationary combustion systems of the new German Länder, in their role as a basis for emissions inventories and the report relative to determination of allocated quantities, were explicitly reviewed for any gaps, completed and corrected as necessary and substantiated". For a detailed description of the procedure used for revising the activity rates for stationary combustion systems, please see the 2010 NIR.

19.1.2 Energy industry (1.A.1)

19.1.2.1 Methodological aspects of determination of emission factors (Chapter 3.2.6.2)

This section of the Annex describes the main steps carried out in the research projects RENTZ et al (2002) and RENTZ et al (2002) und FICHTNER et al (2011) for determination of emission factors. (This description does not apply to the CO_2 emission factors whose determination is described in Annex 2 (Chapter 18.7).)

Determination of emission factors requires detailed analysis of all operational facilities with regard to technologies used and design-specific emission behaviour. Three overarching categories are formed: large combustion systems, combustion systems within the scope of application of the Technical Instructions on Air Quality Control (TA Luft) and gas turbines. Existing plants are classified in terms of emissions-relevant characteristics, and the pertinent emission factors are determined. These so-called "technology-specific" factors can then be aggregated in an adequate manner. This database also provides the basis for estimating future emissions (changes in the overall make-up of the entire group of facilities, in terms of percentage shares for various facility types). This procedure thus consists of the following steps:

21. Characterisation of the technology-specific emissions behaviour of combustion systems. In a first step, the combustion and emissions-reduction technologies used in Germany are briefly described, and the relevant emissions-determining factors are explained. On the basis of this characterisation, emission factors are derived for the various different relevant technologies, differentiated by size class and fuel type. The chosen

classification is also oriented to applicable provisions under immissions-control law, an orientation that permits derived emission factors to be compared with limits applicable now or in the future.

22. Analysis of the relevant category structure
    Emissions calculations must be carried out using emission factors that have the same references as the pertinent energy-input data. The latter (data) are broken down by categories that are derived from the national energy balance – cf. Chapter 3.2 – and are not based on the combustion technologies used. The project has defined and analysed the following categories: Public electricity and heat production (CRF 1.A.1a), Industrial power stations (CRF 1.A.1c for mining-sector power stations; otherwise CRF 1.A.2), District-heating stations (CRF 1.A.1a), Refinery power stations (CRF 1.A.1b), Industrial combustion systems (CRF 1.A.1c and 1.A.2) and Residential and Institutional and commercial (small consumers) (CRF 1.A.4 and 1.A.5).
    In the analysis, the various technologies' contributions to total energy use must be determined. The most important data sources for this include the power-station database of the DFIU (now the KIT), relevant statistics, communications of industry associations (VGB, VDEW, VIK), operator information and technical publications. Furthermore, excerpts of emissions declarations from the years 1996 and 2004, as provided by some Länder authorities, were also evaluated in the present context.
23. Aggregation of emission factors
    On the basis of the percentage contributions for the various technologies – which were determined separately for the old and new Länder – the technology-specific emission factors are aggregated to form category-specific factors. Finally, factors for Germany as a whole are formed. The category-specific factors are sub-divided in accordance with the categories "large combustion systems", "TA Luft combustion systems" and "gas turbines", as well as by fuel type. The aggregated emission factors are formed first for the reference year 1995 (RENTZ et al, 2002) and for the reference year 2004 (FICHTNER et al, 2011).
24. Projections for the years 2000 and 2010 (RENTZ et al, 2002) and for the years 2010 and 2020 (FICHTNER et al, 2011)
    Technology-specific emission factors are defined for the purpose of describing ongoing technical progress. These are derived from characterisation of modern technologies. An increasing contribution of low-emissions technologies to total relevant activity, thus, can be represented by suitably changing the percentage shares for the technologies under consideration. The framework for such carrying forward consists of the relevant applicable provisions under immissions-control law. For the reference year 2010, it is assumed that requirements from the amended Technical Instructions on Air Quality Control (TA Luft) from 2002 and the EU Large Combustion Plants Directive of 2001 have been implemented; for the reference year 2020, we assume that the requirements of Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions have been implemented.

The above-described methods, beginning with characterisation of the emissions behaviour of relevant combustion technologies and gradually leading to aggregated factors at various regional and category-specific levels, make it possible to represent the required factors transparently.

The chosen methods for deriving emission factors for a given reference year are shown in Figure 85 below.

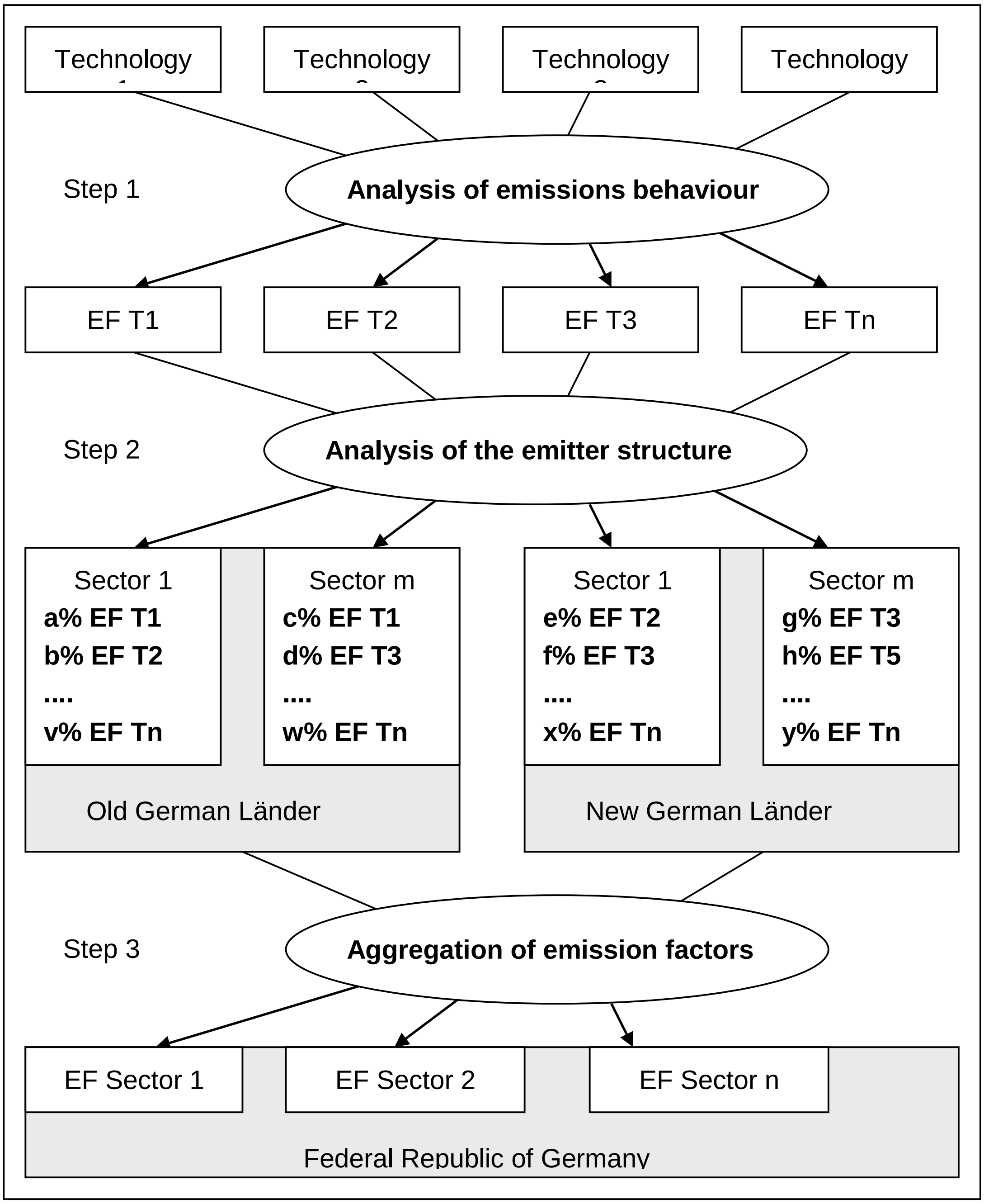

Figure 85: Methods for calculating emission factors

The origins and the quality of the data involved are discussed in detail in the relevant project reports (RENTZ et al, 2002; and FICHTNER et al, 2011). A large part of the data has been taken from the emissions declarations of the German Länder (states) Baden-Württemberg, Brandenburg, North Rhine – Westphalia and Thuringia for 1996, and from the emissions declarations of all Länder (except for Berlin) for the year 2004. The annual pollutant-load data included in those data are based, depending on the pollutant in question, on measurements from continuous monitoring, on individual measurements or on calculations based on physical laws, mass balances or emission factors. In the following, the emissions declarations of the state of Baden-Württemberg are used to show, by way of illustration, what data-determination methods tend to be used for the various types of combustion systems and substances in question. Such analysis makes it possible to classify the quality of the underlying data with regard to the derived technology-specific emission factors. At the same time, the description illustrates the data-evaluation procedure. Where a sufficient amount of data for a source category is available, the relevant value range is characterised via the median and the percentile is characterised at 25 % and 75 %[170]. This produces a robust estimate that, unlike characterisation via the mean value, is not distorted by extreme values. In general, percentiles at 5 % and 95 % are also listed, to describe the distribution of values. Similar percentile evaluations were also carried out for the emissions declarations of the other Federal Länder.

In the following, a distinction is made between measured data (either continuous measurements or individual measurements) and data based on calculations or emission factors. In evaluation, therefore, individual data items are first classified as either "measurements" (M) or "assumptions" (A). This general overview, in turn, is divided into the categories of large combustion systems, TA Luft combustion systems and gas turbines. These are then further subdivided, with regard to declaration obligations, into facilities subject to abbreviated (K) or complete (V) declarations. For each of the three groups of systems, evaluation and derivation of emission factors is carried out, using the sample data from Baden-Württemberg and with classification by "measurements" and "assumptions".

Table 380 provides an overview of the facility types considered, grouped on the basis of their numbers under the 4th Ordinance Implementing the Federal Immission Control Act (BImSchV) and of the type of declaration concerned.

Table 380: Facility types pursuant to Annex of 4th BImSchV (4th Ordinance on Execution of the Federal Immission Control Act)

Index	Large combustion systems (Großfeuerungsanlagen)		Type of declaration required
1 01 1	Power stations	≥ 50 MW for solid, liquid and gaseous fuels	V
1 02A 1	Combustion systems	≥ 50 MW for solid and liquid fuels	V
1 02B 1	Combustion systems	≥ 50 MW for gaseous fuels	V
Index	**TA Luft installations**		**Type of declaration required**
1 02A 2	Combustion systems for heating oil EL)	1 - < 50 MW, solid and liquid fuels (except	V
1 02B 2	Combustion systems	5 - < 50 MW heating oil EL	K
1 02C 2	Combustion systems	10 - < 50 MW for natural gas	K
	Combustion systems installations	10 - < 50 MW, except for natural gas	V
1 03 1	Combustion systems	> 1 MW, other fuels	V

170 For the entire value range of a variable X, the sum-frequency distribution can be used to estimate what percentage of all units considered will have a maximal value of x. That value is referred to as a *quantile* or, when percentage values are being considered, as a *percentile*. The best-known percentile, the one that separates the lower half of all values from the upper half, is the 50th percentile, the so-called *median*. The 25th and 75th percentiles cut off the upper and lower quarters of the distribution. They are thus also referred to as upper and lower *quartiles* or as the first and third *quartile* (with the median being a sort of second quartile).

Index	Gas turbine systems		Type of declaration required
1 05 1	Gas turbines Gas turbines installations	≥ 50 MW for natural gas ≥ 50 MW, except for natural gas	K V
1 05 2	Gas turbines Gas turbines installations	< 50 MW for natural gas < 50 MW, except for natural gas	K V

In the analyses, emissions data are differentiated by combustion technologies. Table 381 provides an overview of this technology classification based on types. Categories 110 to 118 apply mainly to solid fuels, while 120 to 125 apply to liquid fuels and 130 to 132 apply to gaseous fuels.

Table 381: Classification of sources by type of combustion system

Technology	
Type	**Meaning**
110	Combustion systems for solid fuels / waste
111	Filled-shaft combustion systems
112	Combustion with throw feed
113	Combustion systems with pneumatic feed
114	Under-thrust combustion
115	Combustion with mechanically moved grids
116	Dust incineration with dry-ash ventilation
117	Dust incineration with wet-ash ventilation
118	Fluidised-bed combustion
120	Combustion systems for liquid fuels / waste
121	With evaporative burner
122	With pressure-atomising burner
123	With steam-atomising burner
124	With rotation-atomising burner
125	With air-atomising burner
130	Combustion systems for gaseous fuels / waste
131	With atmospheric gas burner
132	With gas-blower burner
141	Multiple-substance combustion systems
142	Mixed combustion
815	Gas turbines

19.1.2.2 CO_2 emissions from flue-gas desulphurisation (CRF 1.A.1, Limestone balance)

In the framework of the research project "limestone balance" ("Kalksteinbilanz"; UBA 2006, FKZ 20541217/02), data for CO_2 emissions from flue-gas desulphurisation were determined for the category Electricity and heat production in public power stations (cf. 3.2.6.2). Flue-gas desulphurisation systems have the task of converting sulphur dioxide in combustion gases, via chemical and physical processes, into substances that are less harmful. Limestone is commonly used as a reagent in flue-gas desulphurisation. Desulphurisation systems are tailored to the applicable requirements under immissions-control law and to the economic value of the resulting residual substances (plaster). The predominant process used in electricity generating plants is limestone scrubbing. Some 87 % of all power stations in Germany, in terms of installed output, use this process (RENTZ et al. 2002b).

Desulphurisation with $CaCO_3$ consists of several sub-reactions. For stoichiometric calculation of limestone inputs in the limestone-scrubbing process, the relevant chemical gross-reaction equation for the process is used (STRAUSS 1998):

$$CaCO_3 + SO_2 + 1/2O_2 + 2H_2O ==> CaSO_4.2H_2O + CO_2$$

This equation can be used to derive the limestone/plaster molar mass ratio. Such derivation shows that 581.39 kilograms of limestone are used per produced tonne of plaster. Plaster-production figures thus can be used to obtain the theoretically maximal limestone inputs for flue-gas desulphurisation in hard-coal-fired and lignite-fired power stations. The plaster-production figures do not indicate whether limestone or lime has been used, however. This problem was resolved with the help of statistics of the German Lime Association (BV Kalk) relative to sales of burnt and unburnt lime for the air-quality-control sector. Using the above reaction equation, the pertinent process-related CO_2 emissions can be determined from the mass relationship between $CaCO_3$ and CO_2. The results of the calculation are shown in the following table. They take account of figures for plaster production in all years between 1990 and 2011. To calculate plaster production for the years 2012 and 2013, we have used the 2011 plaster-production figure as a provisional input figure for the calculation.

Table 382: CO_2 emissions from flue-gas desulphurisation in public power stations

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
CRF 1.A.1					**Figures in Gg**					
CO_2 from flue-gas desulphurisation in public power stations	618	652	629	662	616	683	867	878	1,005	966
Year	**2001**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
CRF 1.A.1					**Figures in Gg**					
CO_2 from flue-gas desulphurisation in public power stations	1,135	1,069	1,094	1,156	1,162	1,142	1,076	1,017	985	995
Year	**2010**	**2011**	**2012**	**2013**						
CRF 1.A.1					**Figures in Gg**					
CO_2 from flue-gas desulphurisation in public power stations	1,003	1028	1,019	979						

Source: Calculation on the basis of of the "limestone balance" project (UBA 2006, FKZ 20541217/02); updated in 2008 (cf. NIR 2009)

In the inventory, these CO_2 emissions were assigned to emissions from use of solid fuels, because such use is the reason for operation of the flue-gas desulphurisation systems and for the systems' CO_2 emissions. Pursuant to expert estimates of the group carrying out the pertinent research, the uncertainty for limestone use and, thus, the uncertainty for related CO_2 emissions, is +/- 10 %.

19.1.3 Transport (1.A.3)

19.1.3.1 Transport – Civil aviation (1.A.3.a)

19.1.3.1.1 Derivation of additional emission factors (1.A.3.a)

Kerosene

Emissions of *sulphur dioxide* depend directly on the sulphur content of the jet kerosene being used. That, in turn, is subject to regional and chronological fluctuations. (IPCC, 2006b) gives an EF of 1 kg SO_2/t kerosene, which is based on a sulphur content of 0.05 % by weight. According to current information of the Fachausschuss für Mineralöl- und Brennstoff-Normung[171] (FAM; technical committee for petroleum and fuels standardisation), jet kerosene in Germany typically has a total sulphur content of about 0.01 % by weight, i.e. one-fifth of the content given by the IPCC. The 2009 inventory report uses a sulphur-content figure of 0.021 % by weight for jet kerosene, on the basis of measurements from the year 1998 (Döpelheuer 2002). It seems plausible that the emission factor would decrease over time as a result of improved procedures and reduced maximum permitted levels. Consequently, a linear reduction is included here between the framework years 1990 (1.08 g SO_2 / kg kerosene), 1998 (0.4 g) and 2009 (0.2 g). In addition, it is assumed that all of the sulphur in the fuel is converted into sulphur dioxide. Because the emission factor depends directly and solely on the sulphur content of the jet kerosene, this emission factor is used for both flight phases.

NO_X and *CO emissions* are calculated with the help of emission factors based on TREMOD-AV calculations. Those results, in turn, are based on aircraft-type-specific and operational-state-specific emission factors taken largely from the EMEP/EEA database. Adjusted emission factors have to be used in some cases, when specific aircraft types cannot be directly allocated to the proper categories, even with the help of data on technically similar aircraft types. Those emission factors were determined via emissions functions, in the context of regression calculations, that calculate the emission factor for each engine type as a function of take-off weight. The basis for those functions consisted of the emission factors for existing aircraft types (cf. in this regard ifeu and Öko-Institut 2010).

In each case, the *NMVOC* emission factors are obtained from the difference between the emission factor for hydrocarbons and that for methane.

Avgas

In the *IPCC Guidelines* (2006a, page 3-64), the emission factors for *nitrous oxide* are explicitly defined as equal to the relevant values given for jet-kerosene use. That assumption has been adopted here – along with the forecasts for jet-kerosene use in cruise phases of national air transports (cruise phase in 2010).

As to fuel properties, there are no fundamental differences between avgas and automobile gasoline[172]. Consequently, values for specific SO_2 emissions from automobile gasoline may be used for avgas. Pursuant to the Fachausschuss für Mineralöl- und Brennstoff-Normung (FAM; technical committee for petroleum and fuels standardisation), the maximum permitted level for

[171] Personal e-mail communication with Dr. Feuerhelm, FAM Hamburg, 9 June 2009

[172] E-mail communication with Mr Winkler of the Mineralölwirtschaftsverband e.V. Association of the German Petroleum Industry, 8 June 2009

total sulphur content in gasoline-station fuel is 10 mg/kg, or 0.001 % by weight, which is one-tenth of the figure given for jet kerosene. As a result, the 2008 emission factor for SO_2 from jet kerosene, reduced by 90 %, is used in the present context.

In each case, the *NMVOC* emission factors are obtained from the difference between the emission factor for hydrocarbons and that for methane.

The other emission factors are not available as special values for average small aircraft. For this reason, they are assumed to be the same as the relevant jet-kerosene emission factors (national, cruise).

Table 383: 2013 emission factors for avgas, in [g/kg] and [kg/TJ]

	EF [g/kg]	EF [kg/TJ]	Remarks regarding the source or calculation
CO_2	3,048	70,000	from 2006 IPCC Guidelines, Table 3.6.4
CH_4	0.36	8.21	same as EF kerosene, LTO/national
N_2O	0.10	2.33	same as EF kerosene, cruise/national
SO_2	0.02	0.51	equivalent to 1/10 of EF kerosene, cruise/national/2008
NO_X	11.39	261	same as EF kerosene, cruise/national
NMVOC	8.09	186	equivalent to EF(HC) minus EF(CH_4)
CO	669.85	15,406	calculated in TREMOD AV
TSP	1.18	27.04	calculated from lead content of AvGas 100 LL
Pb	0.36	17.15	calculated from max. lead content of AvGas 100 L

Source: Öko-Institut (2014)

Table 384: Overview of emission factors for kerosene; in [g/kg]

[g/kg]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
1.A.3.a – Overarching																								
CO_2	3,150																							
SO_2	1.08	1.00	0.91	0.83	0.74	0.66	0.57	0.49	0.40	0.38	0.36	0.35	0.33	0.31	0.29	0.27	0.25	0.24	0.22	0.20	0.20	0.20	0.20	0.20
National, LTO																								
CH_4	0.35																							
N_2O	0.12																							
NO_X	11.73	11.99	12.14	11.43	11.30	11.47	11.49	11.62	11.82	11.97	12.04	12.03	11.75	11.46	11.39	11.20	11.12	11.19	11.62	12.07	12.24	12.17	12.26	12.41
NMVOC	2.03	2.07	1.58	1.44	1.22	1.18	1.25	1.23	1.08	0.94	0.90	0.80	0.83	0.80	0.83	0.87	0.83	0.90	0.86	0.74	0.67	0.72	0.73	0.76
CO	12.26	12.53	12.46	12.95	12.49	12.27	12.00	11.82	12.06	11.83	11.69	11.56	11.82	12.08	12.02	12.15	12.01	11.75	11.41	10.64	10.39	10.60	10.52	10.04
National, cruise																								
CH_4	0.00																							
N_2O	0.10																							
NO_X	16.03	16.75	17.18	16.14	16.09	15.95	15.93	15.93	16.11	16.11	16.32	16.21	16.15	15.95	15.68	15.56	15.50	15.88	16.60	17.00	17.22	17.20	17.47	18.07
NMVOC	0.48	0.54	0.55	0.53	0.49	0.52	0.54	0.57	0.55	0.52	0.53	0.51	0.54	0.53	0.56	0.47	0.41	0.39	0.39	0.38	0.38	0.37	0.37	0.40
CO	4.21	4.30	4.19	4.37	4.21	4.40	4.28	4.38	4.35	4.44	4.29	4.01	3.98	3.91	3.87	3.75	3.70	3.47	3.43	3.55	3.64	3.68	3.55	3.16
International, LTO																								
CH_4	0.13																							
N_2O	0.09																							
NO_X	12.45	12.42	12.40	12.51	12.19	12.20	11.95	11.86	11.98	12.08	12.20	12.29	12.33	12.43	12.50	12.55	12.59	12.72	12.80	13.08	13.34	13.33	13.48	13.70
NMVOC	3.14	3.54	3.42	2.95	3.09	3.09	2.96	2.74	2.82	2.32	2.00	1.87	1.98	1.89	1.61	1.44	1.38	1.29	1.28	1.14	1.00	1.03	0.98	0.88
CO	11.82	11.67	11.42	10.82	11.06	10.93	11.05	11.19	11.19	11.09	10.96	10.80	10.68	10.56	10.44	10.29	10.27	10.08	10.09	10.02	9.85	9.86	9.77	9.50
International, cruise																								
CH_4	0.00																							
N_2O	0.10																							
NO_X	15.47	15.09	14.62	14.58	14.53	14.86	14.16	13.89	14.23	14.34	14.46	14.50	14.53	14.62	14.66	14.75	14.79	14.93	15.01	15.22	15.57	15.65	16.01	16.29
NMVOC	0.35	0.33	0.30	0.28	0.26	0.25	0.24	0.22	0.22	0.21	0.20	0.19	0.18	0.19	0.18	0.17	0.17	0.17	0.17	0.17	0.16	0.16	0.15	0.15
CO	2.12	2.06	1.99	1.91	1.89	1.86	1.75	1.66	1.76	1.72	1.68	1.63	1.58	1.55	1.47	1.45	1.45	1.43	1.40	1.40	1.39	1.37	1.35	1.33

Source: Öko-Institut (2014)

19.1.3.1.2 Detailed overview of the uncertainties underlying the pertinent activity data and emission factors (1.A.3.a)

Table 385: Overview of the applicable partial uncertainties for activity rates and emission factors

Individual components		Partial uncertainties		AR (kerosene & avgas)		SF (LTO/ cruise)		AR (kerosene) LTO and cruise		EM (H_2O) LTO and cruise		EM (CH_4) LTO and cruise		EM (N_2O) LTO and cruise		EM (SO_2) LTO and cruise		EM (H_2O) LTO and cruise		Remaining EM LTO + cruise		**Source / reason for assumptions**
		[%]		Total	n / i	n	i	n	i	n	i	n	i	n	i	n	i	n	i	n	i	
AR of AGEB and BAFA		-5	5	x	x																	Öko-Institut / DIW 2007 Here, the higher uncertainties of the Energy Balance are used. The uncertainties for the BAFA data are +3, -1% (conservatively estimated, using the approach for the uncertainties of mineral-oil statistics, which are based on BAFA data.)
Split factor SF n <> i		-10	10		x																	1990-2002: Calculations pursuant to TREMOD-AV; as of 2003, figures from Eurocontrol. The value here is a mixed value for the entire time series.
AR (kerosene)	n & i	-11	11					x	x													Calculated
Data of the Federal Statistical Office relative to aircraft movements	n	-0.1	0.1			x																Aviation statistics are based on the Transport statistics act (Verkehrsstatistikgesetz - VerkStatG). The data specified by Arts. 12, 13 VerkStatG are recorded. Pursuant to that act, all civil aviation craft, including aircraft, helicopters, airships, motorised gliders, sailplanes and manned balloons, are to be included in relevant surveys, as long as airports/airfields in Germany are involved.
	i	-0.1	0.1				x															
Real-distance addition	n & i	-3	3			x	x															The data of the Federal Statistical Office are oriented to great-circle distances. A detour factor for cruise flight has been used, as a means of estimating the distances actually flown (cf. IFEU and Öko-Institut 2010).
Allocation of consumption values for kerosene to aircraft types	n	-5	5			x																Aircraft types pursuant to the Federal Statistical Office are assigned emission factors from the EMEP-EEA database. There are four different quality levels for such assignment: a) direct, b) via similar types, c) via regression functions depending on take-off weight, and d) lump-sum EF.
	i	-5	5				x															
SF (LTO / cruise)	n	-6	6					x														Calculated
	i	-6	6						x													Calculated
AR (kerosene) LTO and cruise	n	-13	13							x		x		x		x		x		x		Calculated
	i	-13	13								x		x		x		x		x		x	Calculated
Emission factors (EF)	CO_2	5	5							x	x											IPCC 2006, p.3.69; low uncertainty, since the EF depends only on the C content of the fuel.
	CH_4	-57	100									x	x									IPCC 2006, p.3.69; depends on technology and is thus subject to large uncertainty in combination via the Tier 1 approach
	N_2O	-70	150											x	x							
	SO_2	-10	10													x	x					The emission factor depends only on fuel characteristics (sulphur content).
	H_2O	-5	5															x	x			The emission factor depends only on fuel characteristics. Low values, ranging from -4.9 to 1.6, given in Eurocontrol 2004, p.49.
Remaining EF	n & i	-10	10																	x		Assumption – for NO_X, HC and CO, a mean EF is calculated via TREMOD, on the basis of the EF for individual aircraft types
																					x	
Total uncertainty, *above*				+5	+11	+6	+6	+13	+13	+14	+14	+58	+58	+71	+71	+16	+16	+14	+14	+16	+16	
Total uncertainty, *below*				-5	-11	+6	-6	-13	-13	-14	-14	-101	-101	-150	-150	-16	-16	-14	-14	-16	-16	

n = national share; i = international share

Source: ÖKO-INSTITUT (2009)

19.1.3.2 Derivation of activity rates for road transport (1.A.3.b)

19.1.3.2.1 Harmonisation with the Energy Balance

The basis for CSE data collection for the road-transport sector consists of energy consumption data provided by the Working Group on Energy Balances (AGEB). For each year, the sum of the activity rates for the various individual structural elements must correspond to the Energy Balance data, in TJ. The relevant basic Energy Balance data are shown in Table 386 below.

Table 386: Energy inputs in road transports, 1990-2013

Year	Petrol	Diesel fuel	Biodiesel	Bioethanol	LP gas	Natural gas	Petroleum
Energy inputs pursuant to Energy Balances 1990-2013 (last revision: 10/2014), in TJ							
1990	1,330,479	735,920	0	0	138	0	0
1991	1,332,285	785,174	0	0	137	0	0
1992	1,344,129	853,502	0	0	229	0	0
1993	1,350,617	907,787	0	0	184	0	473
1994	1,276,637	932,060	0	0	184	0	559
1995	1,299,982	964,013	1,504	0	138	0	610
1996	1,299,879	964,580	2,046	0	115	0	638
1997	1,297,487	979,586	3,652	0	106	0	357
1998	1,300,463	1,022,794	4,081	0	106	0	637
1999	1,300,602	1,097,036	5,370	0	100	0	637
2000	1,237,055	1,108,105	12,276	0	94	0	414
2001	1,199,318	1,097,416	16,740	0	98	0	471
2002	1,166,381	1,105,842	20,460	0	607	0	472
2003	1,108,989	1,078,352	29,948	0	694	0	0
2004	1,072,720	1,110,931	38,806	1,144	1,887	0	0
2005	992,377	1,078,620	71,824	6,817	2,357	3,127	0
2006	930,834	1,082,042	130,165	13,418	4,605	4,446	0
2007	892,982	1,073,987	143,235	12,061	8,942	5,845	0
2008	854,002	1,102,623	109,393	16,328	15,652	7,144	0
2009	829,227	1,114,939	89,375	23,691	23,842	8,443	0
2010	791,416	1,168,063	88,886	30,577	21,823	8,768	0
2011	787,803	1,197,252	82,810	32,292	23,613	8,771	0
2012	742,000	1,223,718	85,683	32,882	23,532	8,869	0
2013	740,823	1,285,820	75,630	31,756	23,597	8,934	0

Sources: Evaluation tables of the Energy Balances, "Mineralöl-Zahlen 2011" ("2011 Petroleum Data") of the Association of the German Petroleum Industry (MWV) (2014) and "Amtliche Mineralöldaten" ("Official Mineral Oil Statistics").

The Energy Balance is also used to model transport-quantity structures in TREMOD. For example, the German Economic Institute (DIW) carries out a fuel-consumption calculation in order to derive total mileage travelled (DIW, 2002). Some of the results of the calculation, for automobile transports, are entered into TREMOD. The DIW uses a fuel-consumption calculation in order to determine total domestic mileage; TREMOD uses some other sources and assumptions to estimate total domestic mileage – especially for goods transports (cf. the detailed description in ifeu, 2002). This estimate also takes the basic figures of the Energy Balance into account.

On the other hand, due to the many dependencies and uncertainties in the model, and to the basic data that must be taken into account, no feasible means is available for comparing mileage and energy consumption, for each year and each vehicle layer, in such a manner that the results yield the Energy Balance sum and the mileage and mean energy consumption figures in the time series are plausible. For this reason, the TREMOD results for the energy consumption are corrected, at the end of the process, in such a manner that the total for each reference year corresponds to the relevant figure in the Energy Balance.

Since TREMOD calculates energy consumption in tonnes, the results first have to be converted into TJ. For this purpose the net calorific values provided by the Working Group on Energy Balances (AGEB) are used (cf. Table 387).

Table 387: Net calorific values for gasoline and diesel fuel

Year	Gasoline	Diesel fuel
1990-1992	43.543 MJ/kg	42.704 MJ/kg
since 1993	43.543 MJ/kg	42.960 MJ/kg

Source: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen)

The correction factors are derived in TREMOD separately for the various vehicle categories, as follows:

- Firstly, a correction factor for gasoline is derived from the calculated gasoline consumption for all vehicle categories and from gasoline sales pursuant to the Energy Balance.
- The correction factor for gasoline is then also used to bring fuel consumption of vehicles with diesel engines, among automobiles and other vehicles ≤ 3.5 t (light duty vehicles (LNF), and of motor homes and motorcycles (MZR)), into line with the Energy Balance.
- The difference between the corrected diesel-fuel consumption of automobiles and of other vehicles ≤ 3.5 t and the Energy Balance is then allocated to heavy duty vehicles and buses.
- The correction factor for heavy duty vehicles and buses is then calculated from their energy consumption, as calculated in accordance with the domestic principle, and the pertinent difference, as calculated for this group, from the Energy Balance.

The following table summarises the correction factors used.

Table 388: Correction factors for harmonisation with the Energy Balance

	Area of application	Petrol (including bioethanol)	Diesel fuel (including biodiesel)	
		Automobiles, light duty vehicles, motorcycles	Automobiles, light duty vehicles	Heavy duty vehicles, buses
1990	ABL	1.035	1.035	1.126
1990	NBL	1.051	1.051	1.390
1991	ABL	1.032	1.032	1.084
1991	NBL	1.050	1.050	0.983
1992	ABL	1.035	1.035	1.166
1992	NBL	0.990	0.990	1.169
1993	ABL	1.039	1.039	1.277
1993	NBL	0.970	0.970	1.126
1994	ABL	0.981	0.981	1.181
1994	NBL	0.981	0.981	1.181
1995	D	0.993	0.993	1.205
1996	D	0.994	0.994	1.183
1997	D	0.991	0.991	1.186
1998	D	0.984	0.984	1.247
1999	D	0.987	0.987	1.305
2000	D	0.957	0.957	1.334
2001	D	0.944	0.944	1.236
2002	D	0.939	0.939	1.193
2003	D	0.926	0.926	1.134
2004	D	0.933	0.933	1.080
2005	D	0.923	0.923	1.074
2006	D	0.919	0.919	1.090
2007	D	0.916	0.916	1.032
2008	D	0.918	0.918	1.021
2009	D	0.912	0.912	1.056
2010	D	0.901	0.901	1.091
2011	D	0.912	0.912	1.058
2012	D	0.891	0.888	1.132
2013	D	0.912	0.912	1.150

Remark: 1994 correction factors for old German Länder (ABL) and new German Länder (NBL) as for Germany (D) as a whole

19.1.3.2.2 Allocation of biofuels, petroleum, natural gas and LP gas to the structural elements

The Energy Balance includes data on biomass and other fuels, broken down by individual vehicle categories. Those data are allocated as follows:

- The figures for biodiesel and bioethanol are divided in accordance with the various vehicle categories' shares of consumption of the corresponding fossil fuels.
- Petroleum is allocated to buses (on roads outside urban areas) in keeping with the buses' percentage shares of consumption of conventional diesel fuel.

19.1.3.2.3 Activity rate for evaporation

The activity rate for evaporation emissions is set as total gasoline consumption, on *municipal roads (= city)*; the corresponding figure for mopeds is the *total consumption*. The values corrected to the Energy Balance are used.

19.1.3.3 Derivation of emission factors

19.1.3.3.1 Emission factors from TREMOD

In the Central System of Emissions (CSE), implied emission factors, in [kg/TJ] or [kg/t], generated from more-specific TREMOD data, are given for the categories *engine type* and *evaporation*. For gasoline and diesel fuel, those values can be derived directly from TREMOD. To that end, emissions in [t] and energy consumption in [TJ] (converted from the results "energy consumption in t", using the net calorific values pursuant to Table 387) are derived from the TREMOD results and allocated to the relevant structural elements. The implied emission factors result as the quotient of specific emissions in [t] divided by the specific energy consumption in [TJ]. A similar procedure is used for the implied emission factors for evaporation (implied EF = specific evaporation emissions in [kg] / specific consumption (city) in [t])

In general, TREMOD data that have not been corrected in accordance with the Energy Balance are used for this derivation. Use of the so-corrected figures for emissions and energy consumption would lead to the same results, however, since the correction factor cancels out when the implied EF is calculated pursuant to

$$EM_{corr.} \div AR_{corr.} = EM_{TREMOD} \div AR_{TREMOD}.$$

19.1.3.3.2 Emission factors for biodiesel, bioethanol, petroleum, natural gas and LP gas

In all cases, the emission factors for biodiesel and petroleum are set to the same values as those for conventional diesel fuel. The emission factors for bioethanol are set to the same values as those for conventional gasoline.

Exceptions:

- The EF(CO_2) used for biodiesel, 70.8 t/TJ, is a default pursuant to (IPCC, 2006).
- The EF (SO_2) for petroleum is set to 24 kg/TJ for those years in which diesel fuel has a higher value. In all other years, the lower value for diesel fuel is used.

Now, the emission factors for LP gas and natural gas, like those for diesel fuel and gasoline, are being taken from the "Handbook for emission factors of road transports 3.1" ("Handbuch für Emissionsfaktoren des Straßenverkehrs 3.1").

19.1.3.4 Derivation of data for western and eastern Germany, 1994

TREMOD distinguishes between old and new German Länder only until 1993. Since the CSE also requires such differentiation for 1994, a relevant breakdown must be made using simplifying assumptions. The framework conditions include:

- The sum total of activity rates for engine-type categories (Antrieb) must correspond to the relevant Energy Balance values (in each case, for old and new German Länder).
- In the overall result, emissions resulting from linking activity data with emission factors must correspond to the TREMOD results for Germany.

With these framework conditions, a relevant breakdown is possible only under the following assumptions:

- The EF (CSE) for the old and new German Länder are set to the relevant values for all of Germany (TREMOD) in 1994.

- The individual CSE vehicle layers' percentage shares of the activity rates are considered to be the same in each case in the old and new German Länder, and they are the same as the relevant values for all of Germany in 1994.

With these assumptions, the aforementioned conditions are fulfilled. A third framework condition is not fulfilled: the plausibility of emissions results in the time series, in each case, for the old/new German Länder.

19.1.4 CO_2 emissions from co-combustion of lubricants, in various vehicle categories and other mobile sources

The German greenhouse-gas inventory covers CO_2 emissions from co-combustion of lubricants for all mobile sources. In keeping with emissions reporting requirements, emissions from two-stroke gasoline engines are allocated directly to the pertinent emission sources, since in those cases lubricants are seen as part of the relevant fuels (fuel mixtures for two-stroke engines). On the other hand, all co-combustion emissions not caused by two-stroke engines are reported under CRF 2.D.1 product use.

19.1.4.1 CO_2 emissions from lubricant co-combustion in two-stroke gasoline engines

For the entire time series as of 1990, it is assumed, as a simplification, that the two-stroke fuel mixture used in D consists of 49 parts gasoline and one part lubricants (mixture of 1:50). Since the 1980s, this mixing ratio has been the standard for most vehicles with two-stroke engines. No reliable usage data are available on motors that use mixtures of 1:100 (newer mobile devices such as chainsaws, lawnmowers, etc.).

Mopeds and small motorcycles are now virtually the only types of *vehicles with two-stroke engines* that are found on German roads. Until the end of the 1990s, the automobile and utility vehicle fleet included a fraction of vehicles with two-stroke engines produced in the former GDR.

TREMOD contains pertinent separate sets of consumption data for automobiles and light utility vehicles (through 1999) and for mopeds and motorcycles.

TREMODD MM contains current figures on use of *mobile devices with two-stroke engines* for both the Residential (1.A.4.b ii) and Forestry (1.A.4.c ii) sectors.

The figures on gasoline consumption in road transports and by mobile sources in the Commercial and Institutional, and Residential, sectors agree with the corresponding figures in the Energy Balance. To obtain a complete picture of the fuel consumption that must be assigned to two-stroke engines, the relevant quantities of additionally used (i.e. in fuel) lubricants have been calculated – in accordance with the mixing ratio of 1:50. On the basis of an r_V 2 % fraction by volume, the fraction r_E applying to the pertinent energy quantity in [TJ] has to be determined, via the relationship of the two components' average densities (ρ) and net calorific values (H_i):

$$r_{E\%} = r_{V\%} \times \frac{\rho_{lubricant}}{\rho_{fuel}} \times \frac{\mathrm{H_{i_{lubricant}}}}{\mathrm{H_{i_{fuel}}}}$$

$$r_{E\%} = 2\,\% \times \frac{0{,}875\ \frac{\mathrm{kg}}{\mathrm{l}}}{0{,}750\ \frac{\mathrm{kg}}{\mathrm{l}}} \times \frac{40{,}000\ \frac{\mathrm{kJ}}{\mathrm{kg}}}{43{,}543\ \frac{\mathrm{kJ}}{\mathrm{kg}}} = 2{,}1435\,\%$$

The lubricant quantities in [TJ] that are co-combusted as part of two-stroke fuel mixtures are then calculated from the annual energy inputs in [TJ] that are assigned to two-stroke engines and the pertinent fraction r_E. The CO_2 emissions from lubricant co-combustion in two-stroke engines in road transports can thus be listed separately.

In the category of mobile machines and devices, no separate lubricant quantities in [TJ] are calculated. Instead, in a simplification the energy inputs applying to these two-stroke engines are upwardly corrected by 2.1435 %. The CO_2 emissions from lubricant co-combustion in two-stroke engines in mobile machines and devices are thus included in the total emissions of the relevant sectors.

Emission factors

To make it possible to show CO_2 emissions from combusted two-stroke fuel mixtures in the inventory, weighted implied emission factors were formed for the entire time series. These consist of a 49/50ths fraction based on the year-specific EF(CO_2) for gasoline (OK) (or the Tier 1 EF for bioethanol (BE)) and a 1/49ths fraction based on the default value 73,300 kg CO_2/TJ for lubricants (S) pursuant to (IPCC, 2006). These IEF, which include 2 % by vol. for lubricants, are thus slightly higher than the values used for the relevant pure fuels (gasoline, bioethanol).

Table 389: Derivation of EF(CO_2) for two-stroke fuel mixtures; in [g/TJ]

	1990	1995	2000	2005	2010	2011	2012	2013
EF_{OK}	73.07	73.08	73.09	73.10	73.12	73.03	73.09	73.09
EF_{BE}	71.61							
EF_{S}	73.30 (pursuant to IPCC Guidelines 2006, Table 2.4)							
IEF_{OK+S}	73.07	73.08	73.10	73.11	73.12	73.03	73.10	73.10
IEF_{BE+S}	71.64							

The CO_2 emissions resulting from lubricant co-combustion in two-stroke gasoline engines are thus already included in the emissions reported for the relevant sectors (1.A.3.b – Road transportation, 1.A.4.b ii – Residential, 1.A.4 c ii – Forestry) and are not listed separately in the CRF tables. Table 390 thus provides an overview of these CO_2 emissions:

Table 390: EM(CO_2) from lubricants co-combusted in two-stroke gasoline engines; in [kt]

	1990	1995	2000	2005	2010	2011	2012	2013
1.A.3.b	177.12	24.56	6.55	6.46	6.42	6.62	6.44	6.56
1.A.4.b ii	2.34	1.80	1.20	1.13	1.43	1.69	1.53	1.55
1.A.4.c ii	4.53	3.85	3.44	3.65	2.03	1.71	0.50	0.51
Total	**183.99**	**30.21**	**11.19**	**11.24**	**9.88**	**10.02**	**8.47**	**8.62**

CO_2 emissions from lubricant co-combustion in four-stroke engines and in other engines in vehicles and mobile sources

19.1.4.2 CO_2 emissions from lubricant co-combustion in four-stroke engines and in other engines in vehicles and mobile sources

The data on the total lubricant quantities used in connection with lubricant co-combustion in four-stroke gasoline engines and in other engines in vehicles and mobile sources are very spotty. As a result, the co-combusted quantities are calculated largely on the basis of figures provided by the *Verband Schmierstoff-Industrie* e. V. (VSI; the association of the German lubricant industry) on the relevant fuel quantities.

Pursuant to (VSI, 2014) the following co-combustion fractions, with respect to the relevant fuel quantities used, are achieved in the various usage areas:

Table 391: Overview of the specific co-combustion fractions used

Sector	Fuel	Fraction	Source / remark
1.A.2.g vii	O	0.00 %	Assumption, based on (VSI 2012)
	D	0.10 %	Pursuant to (VSI, 2012)
1.A.3.a / 1.D.1.a	K	0.10 %	Pursuant to (VSI, 2012)
	F	0.10 %	Like kerosene
1.A.3.b	All	-	Calculation for the overall sector, on the basis of TREMOD
1.A.3.c	D	0.05 %	Pursuant to (VSI, 2012)
1.A.3.d / 1.D.1.b	D	0.15 %	Pursuant to (VSI, 2012)
	S	0.15 %	Like diesel fuel
1.A.4.a ii	D	0.10 %	Like 1.A.3.b; pursuant to (VSI, 2012)
	LPG		Like 1.A.3.b; pursuant to (VSI, 2012)
1.A.4.b ii	O	0.00 %	Assumption, based on (VSI 2012)
1.A.4.c ii (i)	O	0.00 %	Assumption, based on (VSI 2012)
	D	0.10 %	Like 1.A.3.b; pursuant to (VSI, 2012)
1.A.4.c ii (ii)	D	0.10 %	Like 1.A.3.b; pursuant to (VSI, 2012)
1.A.4.c iii	D	0.15 %	Like 1.A.3.d; pursuant to (VSI, 2012)
	S	0.15 %	Like diesel fuel
1.A.5.b i	O	0.00 %	Assumption, based on (VSI 2012)
	D	0.15 %	Like 1.A.3.d; takes account of armored vehicles
1.A.5.b ii	K	0.10 %	Like 1.A.3.a / 1.D.1.a
	F	0.10 %	Like 1.A.3.a / 1.D.1.a
1.A.5.b iii	D	0.15 %	Like 1.A.3.d; pursuant to (VSI, 2012)
	S	0.15 %	Like diesel fuel

O: gasolines (including bioethanol), only four-stroke engines; D: diesel fuel (including biodiesel), K: kerosene; F: avgas; S: heavy fuel oil; E: natural gas (CNG); F: LP gas (LPG)

Table 392: EM(CO_2) from co-combusted lubricants; in [kt] (cf. CRF 2.D.1)

	1990	1995	2000	2005	2010	2011	2012	2013
1.A.2.g vii	3.47	3.26	3.12	2.47	2.75	2.96	2.90	2.93
1.A.3.a	0.25	0.22	0.27	0.26	0.24	0.22	0.22	0.21
1.A.3.b	88.68	104.70	114.56	118.33	121.52	123.71	123.68	124.87
1.A.3.c	1.41	1.14	0.93	0.68	0.57	0.58	0.53	0.51
1.A.3.d	5.31	4.17	2.99	2.86	2.53	2.60	2.61	2.61
1.A.4.a ii	0.57	0.47	0.47	0.44	0.49	0.48	0.47	0.48
1.A.4.b ii	*Here, only use of two-stroke gasoline engines*							
1.A.4.c ii	4.16	3.44	3.38	3.21	3.67	3.65	3.59	3.68
1.A.4.c iii	0.08	0.06	0.06	0.06	0.06	0.05	0.05	0.05
1.A.5.b i	1.65	0.88	0.15	0.38	0.12	0.07	0.11	0.08
1.A.5.b ii	0.28	0.12	0.07	0.02	0.02	0.03	0.01	0.02
1.A.5.b iii	1.08	0.73	0.62	0.46	0.41	0.39	0.37	0.35
NATIONAL	**106.94**	**119.19**	**126.62**	**129.17**	**132.38**	**134.74**	**134.54**	**135.79**
1.D.1.a	1.19	1.50	1.92	2.27	2.42	2.32	2.50	2.54
1.D.1.b	8.93	7.61	8.21	9.91	11.39	11.22	10.31	9.20

19.1.5 CO_2 emissions from use of AdBlue® in road transports and off-road vehicles

Since 2005, increasing numbers of vehicles have been in service in Germany that are equipped with SCR catalytic converters. Such catalytic converters reduce NO_x emissions with the help of an added reducing agent, an aqueous urea solution (with a mean urea content, pursuant to DIN 70070, of 32.5 %), whose chemical transformation releases carbon dioxide. In Germany, the product AdBlue® is used almost exclusively for this purpose (VDA, 2014).

In 2013, to address a lack of current, comprehensive statistics or market studies on sales of AdBlue® or on the CO_2 emissions caused by AdBlue®, the ifeu Institute in Heidelberg conducted a relevant survey (IFEU, 2013). In the framework of that survey, the AdBlue® quantities used were modelled, and the resulting CO_2 emissions calculated, on the basis of fuel consumption data for vehicles equipped with SCR catalytic converters.

Table 393: Modelled quantities of AdBlue® used; figures in [kt]

	2005	2006	2007	2008	2009	2010	2011	2012	2013
1.A.3.b	**5**	**25**	**79**	**154**	**194**	**244**	**291**	**339**	**387**
Automobiles	0	0	0	0	1	2	5	9	17
Light duty vehicles	0	0	0	0	0	0	0	0	0
Heavy duty vehicles	5	24	76	148	184	230	272	310	348
Buses	0	1	2	5	7	9	10	15	16
Other motor vehicles	0	0	1	1	2	3	4	5	6

No data on SCR vehicles in the off-road sector (especially the construction sector) are available at present. It is expected that such vehicles will be introduced to the market within the next few years.

The resulting CO_2 emissions are calculated in keeping with the following formula, pursuant to (IPCC, 2006):

$$EM_{CO_2} = AR_{AdBlue®} \times \frac{12}{60} \times \frac{32,5}{100} \times \frac{44}{12}$$

The following table presents the so-determined CO_2 emissions, for the period 2005 through 2013, from use of AdBlue® in vehicles equipped with SCR catalytic converters.

Table 394: CO_2 emissions resulting from use of AdBlue®; figures in [kt]

	2005	2006	2007	2008	2009	2010	2011	2012	2013
1.A.3.b	**1**	**6**	**19**	**37**	**46**	**58**	**69**	**81**	**92**
Automobiles	0	0	0	0	1	1	1	2	4
Light duty vehicles	0	0	0	0	0	0	0	0	0
Heavy duty vehicles	1	6	18	35	44	55	65	74	83
Buses	0	1	1	1	2	2	2	3	4
Other motor vehicles	0	0	1	1	1	1	1	1	1

In the German GHG inventory, these emissions are reported, pursuant to footnote (6) to CRF Table 2(I).A-Hs2, under*2.D.3 – Non-energy products from fuels – Other*.

19.2 Other detailed methodological descriptions for the source category "industrial processes" (2)

19.3 Other detailed methodological descriptions for the category "Agriculture" (3)

19.3.1 Calculation of the emissions for additional animal categories

Under "Other Livestock", the CRF tables pursuant to IPCC (2006) list the following additional animal categories that the old CRF tables did not include:

- Deer,
- Rabbits,
- Reindeer,
- Ostriches,
- Fur-bearing animals.

No reindeer are kept in Germany. In the following chapters, the greenhouse-gas emissions from the other four categories are calculated, by way of example, and using Tier 1 methods, for one year. Table 395 summarises the results of these calculations. These data serve as the basis for concluding that the relevant emissions are insignificant and thus do not have to be reported in the NIR.

Table 395: Total GHG emissions of deer, rabbits, ostriches and fur-bearing animals

	CH_4 [Gg a^{-1}]	N_2O [Gg a^{-1}]	CO_{2eq} [Gg a^{-1}]
Total	**5.635**	**0.1119**	**174.20**
Deer	5.348	0.0829	158.42
Rabbits	0.194	0.0143	9.09
Ostriches	0.043	0.0024	1.81
Fur-bearing animals (mink)	0.050	0.0122	4.88

19.3.1.1 Animal-place figures

In Germany, no official counts are taken of populations of deer, rabbits, ostriches and fur-bearing animals. Table 396 presents estimates of the Federal Statistical Office concerning the average animal populations (C. Schreiner, personal communication). These figures are interpreted as numbers of continuously occupied animal places (AAP) (cf. Chapter 5.1.3.2). The FAO also provides figures for rabbits, but those figures are far lower than the figures estimated by the Federal Statistical Office. For this reason, the approach used here may be considered a conservative one.

Table 396: Average annual animal populations, pursuant to estimates of the Federal Statistical Office

	Population	Source
Deer	264,500	Landesverbände für landwirtschaftliche Wildtierhaltung (state associations for agricultural husbandry of wild animals); survey conducted in the period 2008/2009
Rabbits	440,000	Bundesverband deutscher Kaninchenfleisch- und –wollerzeuger e.V. (national association of German producers of rabbit meat and rabbit fur)
Ostriches	7,632	Tierseuchenkasse (animal diseases fund; 2012)
Fur-bearing animals (mink)	63,500	Länderabfrage zur Haltung von Pelztieren (State survey on husbandry of fur-bearing animals; last revision March 2012)

19.3.1.2 CH_4 emissions from enteric fermentation

No CH_4 emissions from enteric fermentation are calculated for ostriches, since IPCC (2006) does not specify any methods for such calculation. The emissions for the categories deer, rabbits and fur-bearing animals are calculated by multiplying the relevant numbers of animals by the pertinent emission factors.

For deer, the CH_4 default emission factor in IPCC (2006)-10.28, Table 10.10, is used (20 kg pl^{-1} a^{-1}).

IPCC (2006) does not provide an emission factor for rabbits. Pursuant to footnote 1 for Table 10.10, pg. 10.28, in IPCC (2006), the emission factor can be approximated by selecting an emission factor for an animal with a similar digestive system and then scaling that emissions factor using the ratio of the weights of the animals raised to the 0.75 power. For such estimation, the horse was chosen as the comparison animal, since it is neither a ruminant (cattle, sheep, goats) nor an omnivore (swine). According to IPCC (2006)-10.28, Table 10.10, a horse weight of 550 kg per animal should be used for the calculation. The specified weight for rabbits is 3.0 kg (final live weight of a fattening rabbit, pursuant to LfL Bayern (Bavarian state office for agriculture) [http://www.lfl.bayern.de/itt/tierhaltung/37339/]). From the CH_4 emission factor for horses (18 kg pl^{-1} a^{-1}, IPCC (2006)-10.28, Table 10.10), one then obtains a CH_4 emission factor of 0.36 kg pl^{-1} a^{-1} for rabbits.

For fur-bearing animals, we have adopted the CH_4 emission factor used by other countries (Estonia, Finland, Iceland, Norway; the 2014 NIR in each case), 0.1 kg pl^{-1} a^{-1}.

Table 397 shows the annual emissions from enteric fermentation calculated for deer, rabbits and fur-bearing animals.

Table 397: CH_4 emissions from enteric fermentation for deer, rabbits and fur-bearing animals

	EF [kg pl^{-1} a^{-1}]	CH_4 [Gg a^{-1}]	CO_{2eq} [Gg a^{-1}]
Total		**5.45**	**136.37**
Deer	20.00	5.29	132.25
Rabbits	0.36	0.16	3.96
Fur-bearing animals (mink)	0.10	0.0064	0.16

19.3.1.3 CH_4 emissions from manure management

The default emission factors specified in IPCC (2006)-10.83, Table 10A-9, have been used. The resulting emissions are shown in Table 398.

Table 398: CH_4 emissions from manure management for deer, rabbits, ostriches and fur-bearing animals

	EF [kg pl^{-1} a^{-1}]	CH_4 [Gg a^{-1}]	CO_{2eq} [Gg a^{-1}]
Total		**0.180**	**4.50**
Deer	0.22	0.058	1.45
Rabbits	0.08	0.035	0.88
Ostriches	5.67	0.043	1.08
Fur-bearing animals (mink)	0.68	0.043	1.08

19.3.1.4 N_2O emissions from manure management

To calculate N_2O emissions from manure management, one must know the relevant N excretions. It is also useful to know how the relevant animal population is divided among the applicable housing systems. The latter factor is not known for deer, rabbits, ostriches and fur-bearing animals in Germany. As a simplification, therefore, year-round free-range management is assumed for deer, while year-round housing in solid-manure-based stable systems is assumed for rabbits, fur-bearing animals and ostriches. With regard to the N excretions, cf. Chapter 19.3.1.4.1. The resulting N_2O emissions are listed in Chapter 19.3.1.4.2.

19.3.1.4.1 N excretions

Neither IPCC (2006) nor EMEP (2013) specify a default value for the N excretions of deer. The following table shows the N-excretion values used by those countries that report on deer emissions (2012 NIR). The German calculations have been carried out with the value used by Denmark (16 kg pl^{-1} a^{-1}), since it can be assumed that the average N excretions of deer in Denmark do not differ significantly from those of deer in Germany. The resulting value is only slightly higher than the mean value of all data in Table 399 (15.1 kg pl^{-1} a^{-1}).

Table 399: Deer: N excretions N_{excr} reported by other countries in the 2012 NIR

Deer	N_{excr} [kg pl^{-1} a^{-1}]	Remarks
Denmark	16	
UK	13	
Austria	13.1	The value for sheep has been used
Norway	12	
Russia	8.48	
New Zealand	28.23	

For rabbits, IPCC 2006, pg. 10.59, Table 10.19, specifies a default N-excretion value of 8.1 kg pl^{-1} a^{-1}. That value seems unrealistic, since it is of the same order of magnitude as the total weight gain per animal place and year. Assuming about four rounds of fattening per year (n_{round}, derived from a 87-day duration of fattening pursuant to LfL Bayern (Bavarian state office for agriculture) (http://www.lfl.bayern.de/itt/tierhaltung/37339/)) and a final live weight of about 3 kg $animal^{-1}$ (cf. also LfL Bayern), the latter works out to about 12 kg pl^{-1} a^{-1}. For this reason, the N excretions of rabbits are estimated on the basis of the relevant N balance for the animals; cf. Equation 49:

Equation 49: Calculation of the N excretions of rabbits (N balance)

$$N_{\text{excr, rabbit}} = n_{\text{round}} \cdot \Delta w_{\text{round}} \cdot (x_{\text{N}} \cdot x_{\text{XP, feed}} \cdot x_{\text{feed}} - x_{\text{N, ret}})$$

Where

$N_{excr, rabbit}$	N excretions (in kg $place^{-1}$ a^{-1})
n_{round}	Number of fattening rounds per year (in rounds a^{-1})
Δw_{round}	Weight gain per fattening round (in kg $round^{-1}$ $place^{-1}$)
x_N	N content of raw protein (1 / 6.25 kg kg^{-1})
$x_{XP, feed}$	Raw protein content of feed (fresh matter) (in kg kg^{-1})
x_{feed}	Feed input (fresh matter) per kg of weight gain (in kg kg^{-1})
$x_{N, ret}$	Specific N retention (kg kg^{-1})

In a conservative approach, and as a simplifying approximation, Δw_{round} is considered to be equal to the end weight after fattening (see above). The raw protein content of the feed, $x_{XP,feed}$, pursuant to http://www.meissner-widder-kaninchen.de/F_WERT_TAB1.html, is about 0.17 kg kg^{-1}. The feed input x_{feed} is about 3.5 kg kg^{-1} (LfL Bayern). Pursuant to DLG (2005), p.12, $x_{n,ret}$ = 0.03 kg kg^{-1}. Equation 49 then yields an N-excretion value of 0.8 kg pl^{-1} a^{-1}.

For ostriches, neither IPCC (2006) nor EMEP (2013) specifies default values for N excretions. The values listed in Table 11 have been taken from the CRF tables (2012 NIR) of those countries that report on ostriches.

Table 400: Ostriches: N excretions N_{excr} reported by other countries in the 2012 NIR

Ostriches	N_{excr} [kg pl^{-1} a^{-1}]	Remarks
Denmark	15.6	
Norway	12	
Luxembourg	12	
Australia	7	N excretions of ostriches and emus

As with deer, the German calculations have been carried out using the Danish value (15.6 kg pl^{-1} a^{-1} N).

For mink, IPCC (2006)-10.59, Table 10.19, specifies a default N-excretion value of 4.59 kg pl^{-1} a^{-1} N.

19.3.1.4.2 Direct N_2O emissions from manure management

The direct N_2O emissions from manure management for rabbits and fur-bearing animals have been calculated by multiplying the number of animal places by the annual N excretions per place, the national German N_2O-N emission factor for solid manure (0.013 kg kg^{-1}, Rösemann et al., 2015) and the molar ratio of N_2O to N (44/28). The emissions for ostriches have been calculated in a similar manner, with the exception that the relevant IPCC default value of 0.001 kg kg^{-1} (IPCC (2006)-10.63, Table 10.21) has been used as the emission factor. No N_2O emissions occur in the area of manure management for deer, since free-range management may be considered equivalent to "grazing" in this regard. The resulting emissions are reported together with the direct N_2O emissions from soils; cf. Chapter 19.3.1.6.

Table 401: Direct N_2O emissions from manure management for deer, rabbits, ostriches and fur-bearing animals

	N_{excr} [kg pl^{-1} a^{-1}]	N_2O [Gg a^{-1}]	CO_{2eq} [Gg a^{-1}]
Total		**0.013**	**3.97**
Deer	16	0.000	0.00
Rabbits	0.8	0.007	2.14
Ostriches	15.6	0.0002	0.06
Fur-bearing animals (mink)	4.59	0.006	1.77

19.3.1.5 Indirect N_2O emissions from manure management

As for other animals (cf. Chapter 5.3.1), indirect N_2O emissions from leaching / surface runoff are not calculated. The following section describes the calculation of indirect N_2O emissions from deposition of reactive nitrogen from NH_3 and NO emissions from housing and storage. Due to a lack of relevant data, nitrogen inputs from bedding material cannot be taken into account.

First, the NH_3 and NO emissions from housing and storage are determined. The procedure for calculating the NO emissions is similar to that for calculating direct N_2O emissions from housing and storage (cf. Chapter 19.3.1.4.2). As was the case for the other animals (cf. Chapter 5.3.4.2.2), the emission factor is set to ten percent of the N_2O emission factor: 0.0013 kg kg^{-1} for rabbits and fur-bearing animals, and 0.0001 kg kg^{-1} for ostriches.

The NH_3 emissions from housing are calculated by multiplying the excreted quantity of TAN (total ammoniacal nitrogen) by the relevant emission factor. The TAN quantity is obtained as the product of N excretions and the excretions' relative TAN content. The NH_3 emissions from storage are proportional to the TAN quantity that remains following deduction of N losses due to NH_3 emissions from the stable. The pertinent proportionality factor is the emission factor for storage. No data on TAN content and emission factors are available for rabbits and ostriches. For this reason, the relevant default values for horses and geese in EMEP (2013)-3B-27 have been used. The data ultimately used are listed in Table 402, with the emission factors given in kg NH_3-N per kg of TAN. For deer, the calculation is not required, since deer are assumed to remain outdoors year-round.

Table 402: Input data for calculation of NH_3 emissions (emission factors [EF] in kg NH_3-N per kg TAN)

	TAN content [%]	EF stable [kg kg^{-1}]	EF storage [kg kg^{-1}]	Remarks
Rabbits	60	0.22	0.35	Default for horses; EMEP (2013)-3B-27
Ostriches	70	0.57	0.16	Default for geese; EMEP (2013)-3B-27
Fur-bearing animals (mink)	60	0.27	0.09	Default; EMEP (2013)-3B-27

The resulting deposition of reactive nitrogen (N_{reac}), and the then-resulting indirect N_2O emissions, are given in Table 403. Pursuant to IPCC (2006)-11.24, Table 11.3, emission factor EF_4 = 0,01 kg N_2O-N per kg N_{reac} has been used.

Table 403: Indirect N_2O emissions from deposition of reactive nitrogen from NH_3 and NO emissions from housing and storage

	N_{reac}[Gg a^{-1}]	N_2O [Gg a^{-1}]	CO_{2eq} [Gg a^{-1}]
Total	**0.2169**	**0.00341**	**1.02**
Rabbits	0.1046	0.00164	0.49
Ostriches	0.0533	0.00084	0.25
Fur-bearing animals (mink)	0.0591	0.00093	0.28

19.3.1.6 Direct N_2O emissions from agricultural soils

Application of manure of rabbits, ostriches and fur-bearing animals, and free-range husbandry of deer, leads to direct N_2O emissions from agricultural soils.

The emissions from manure application are calculated by multiplying the N quantity that remains, following N losses (as NH_3, N_2O, NO and N_2) from housing and storage, by the IPCC default emission factor EF_1 (0.01 kg N_2O-N per kg N, IPCC (2006)-11.11, Table 11.1) and the molar ratio 44/28.

The N_2O emissions caused by deer are obtained by multiplying the number of animals by the TAN excretions, the N_2O-N emission factor for grazing and the molar ratio 44/28. The applicable TAN quantity is obtained as the product of N excretions and the excretions' relative TAN content. Since the latter factor is unknown, the relevant value for sheep pursuant to EMEP (2013)-3B-27 (50 %) is used. The emission factor used is the $EF_{3PRP,SO}$ given in IPCC (2006)-11.11, Table 11.1 for sheep and other animals (0.01 kg N_2O-N per kg N excretions).

Table 404 shows the pertinent emissions, along with the N quantities used to obtain them, via multiplication by the relevant emission factors and the molar ratio 44/28.

Table 404: Direct N_2O emissions from soils as a result of free-range husbandry of deer and of application of manure of rabbits, ostriches and fur-bearing animals.

	N [Gg a^{-1}]	N_2O [Gg a^{-1}]	CO_{2eq} [Gg a^{-1}]
Total	**4.744**	**0.0745**	**22.21**
Deer	4.232	0.0665	19.82
Rabbits	0.229	0.0036	1.07
Ostriches	0.065	0.0010	0.31
Fur-bearing animals (mink)	0.217	0.0034	1.02

19.3.1.7 Indirect N_2O emissions from agricultural soils

To calculate the indirect emissions from deposition of reactive nitrogen, one must know the NH_3-N emissions from free-range husbandry of deer and from manure application, along with the relevant NO-N emissions. Table 406 shows the parameters that are used, with the pertinent emission factors given in kg NH_3-N per kg TAN.

Table 405: Parameters for calculation of indirect N_2O emissions from deposition of reactive nitrogen as a result of free-range husbandry and of application (emission factors [EF] in kg N_2O-N per kg of reactive nitrogen)

	EF_{NH3-N} Free-range	EF_{NH3-N} application	Remarks
Deer	0.09		Default for sheep; EMEP (2013)-3B-27
Rabbits		0.90	Default for horses; EMEP (2013)-3B-27
Ostriches		0.45	Default for geese; EMEP (2013)-3B-27
Fur-bearing animals (mink)		0.90	Default; EMEP (2013)-3B-27

The NO-N emissions from free-range husbandry of deer are calculated with the default emission factor, 0.007 kg kg^{-1} N (EMEP (2007)-B1020-12). The NO-N emissions from application, like the N_2O-N emissions from application, are calculated with the emission factor 0.012 kg NO-N per kg N (EMEP (2013)-3D-11; that source gives the EF as 0.026 kg NO per kg N).

Table 406: Indirect N_2O emissions from deposition of reactive nitrogen (N_{reac}) from NH_3 and NO emissions from free-range husbandry of deer and from application

	N_{reac} [Gg a^{-1}]	N_2O [Gg a^{-1}]	CO_{2eq} [Gg a^{-1}]
Total	**0.424**	**0.0067**	**1.99**
Deer	0.220	0.0035	1.03
Rabbits	0.090	0.0014	0.42
Ostriches	0.014	0.0002	0.07
Fur-bearing animals (mink)	0.100	0.0016	0.47

The indirect emissions from leaching / surface runoff are calculated by multiplying the N quantity available in the soil (N_{soil}) by $FRAC_{Leach}$ (0.3 kg kg^{-1} pursuant to IPCC (2006)-11.24, Table 11.3) and the emission factor EF_5 = 0.0075 (IPCC (2006)-11.24, Table 11.3). The N quantity available in the soil is calculated via the same procedure used for the other animals; cf. Chapter 5.1.5.1.4.

Table 407: Indirect N_2O emissions from the soil as a result of leaching / surface runoff

	N_{soil} [Gg a^{-1}]	N_2O [Gg a^{-1}]	CO_{2eq} [Gg a^{-1}]
Total	**3.395**	**0.0139**	**4.15**
Deer	3.673	0.0130	3.87
Rabbits	0.118	0.0004	0.12
Ostriches	0.045	0.0002	0.05
Fur-bearing animals (mink)	0.098	0.0003	0.10

19.3.2 Distributions of housing, storage and application procedures, and of grazing data (CRF 3.B, 3.D)

Table 408 through Table 411 show the applicable distributions, aggregated at the national level (and rounded to whole-number percentages), of housing, storage and application procedures. They also include data on grazing. Buffalo, and mules and asses, are not listed separately in the following tables, because buffalo data are reported together with cattle data, and data for mules and asses are reported together with data for horses (cf. Chapter 5.1.3.2.2).

The relevant emissions were calculated not with the data shown in Table 408 through Table 411, but with the data underlying those data. Those underlying data have state-level (German-Länder-level) resolution. The tables also include information relative to emission factors (including that for NH_3). For further details, cf. RÖSEMANN et al. (2015).

Table 408: Frequency distributions of animal housing procedures (in %), and pertinent litter quantities and NH_3 emission factors

livestock category	housing type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	bedding material (straw) kg place d^{-1}	NH_3-N EF for housing, kg NH_3-N per kg TAN in excreta
dairy cattle	tied systems, straw based	31	31	31	31	15	15	15	15	13	13	13	12	12	12	11	11	10	10	10	9	9	9	9	9	5.0	0.066
	tied systems, slurry based	37	37	37	37	36	36	36	36	34	34	33	31	30	28	27	25	24	23	21	20	18	18	18	18		0.066
	loose housing, straw based	2	2	2	2	3	3	3	3	3	3	4	4	5	5	6	6	7	7	8	8	9	9	9	9	5.0	0.197
	loose housing, slurry based	29	29	29	29	46	46	46	46	49	49	50	52	53	55	56	57	59	60	61	63	64	64	64	64		0.197
	loose housing, deep bedding	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8.0	0.197
	time spent on pastures (in % of year)	18	18	18	18	14	14	14	14	13	13	13	13	12	12	12	11	11	11	11	11	10	11	11	11		
male beef cattle	tied systems, straw based	4	4	4	4	2	2	2	2	2	2	2	3	3	4	4	5	5	6	6	6	7	7	7	7	2.0	0.066
	tied systems, slurry based	7	7	7	7	4	4	4	4	4	4	4	5	5	6	7	7	8	8	9	10	10	10	10	10		0.066
	loose housing, slurry based	83	83	83	83	89	89	89	89	91	91	87	84	81	78	74	71	68	65	61	58	55	55	55	55		0.197
	loose housing, sloped floor	5	5	5	5	4	4	4	4	3	3	6	8	10	12	15	17	19	21	24	26	28	28	28	28	2.5	0.213
	time spent on pastures (in % of year)	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	4	4	3	3	3		
heifers	tied systems, straw based	8	8	8	8	8	8	8	8	8	8	9	9	9	9	9	9	10	10	10	10	10	10	10	10	2.0	0.066
	tied systems, slurry based	15	15	15	15	17	17	17	17	17	17	16	16	15	14	14	13	12	12	11	10	10	10	10	10		0.066
	loose housing, slurry based	48	48	48	48	49	49	49	49	49	49	49	49	48	48	47	47	47	46	46	45	45	45	45	45		0.197
	loose housing, straw based	29	29	29	29	25	25	25	25	25	25	26	27	28	29	30	31	32	32	33	34	35	35	35	35	3.0	0.197
	time spent on pastures (in % of year)	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	21		
calves	tied systems, straw based	50	50	50	50	50	50	50	50	50	50	50	50	50	0	0	0	0	0	0	0	0	0	0	0	2.5	0.066
	loose housing, deep bedding	50	50	50	50	50	50	50	50	50	50	50	50	50	100	100	100	100	100	100	100	100	100	100	100	2.5	0.197
	time spent on pastures (in % of year)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		

livestock category	housing type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	bedding material (straw) kg place d^{-1}	NH_3-N EF for housing, kg NH_3-N per kg TAN in excreta
suckler cows	tied systems, straw based	6	6	6	6	6	6	6	6	6	6	7	8	9	10	11	12	13	14	15	16	17	17	17	17	5.0	0.066
	tied systems, slurry based	3	3	3	3	3	3	3	3	2	2	2	3	3	3	3	4	4	4	5	5	5	5	5	5		0.066
	loose housing, slurry based	9	9	9	9	8	8	8	8	6	6	7	8	9	9	10	11	12	12	13	14	14	14	14	14		0.197
	loose housing, deep bedding	82	82	82	82	83	83	83	83	86	86	84	82	80	78	76	74	71	69	67	65	63	63	63	63	8.0	0.197
	time spent on pastures (in % of year)	41	40	42	42	42	42	43	43	44	44	44	44	45	44	45	45	45	46	46	47	47	47	47	47		
mature males > 2 years	tied systems, straw based	16	16	16	16	15	15	15	15	14	14	14	14	15	15	15	15	15	15	15	15	15	15	15	15	5.0	0.066
	tied systems, slurry based	10	10	10	10	9	9	9	9	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8		0.066
	loose housing, slurry based	38	38	38	38	35	35	35	35	36	36	36	36	35	35	35	35	34	34	34	34	33	33	33	33		0.197
	loose housing, straw based	37	37	37	37	41	41	41	41	41	41	41	42	42	42	43	43	43	44	44	44	44	44	44	44	5.0	0.197
	time spent on pastures (in % of year)	35	33	33	34	33	33	33	32	33	33	32	32	32	32	32	33	33	33	34	34	34	34	34	34		
fattening pigs	fully slatted floor, slurry	49	49	49	49	57	57	57	57	62	62	63	64	64	65	66	67	68	69	70	71	72	72	72	72		0.3
	partly slatted floor, slurry	40	40	40	40	34	34	34	34	31	31	31	30	29	28	27	26	26	25	24	23	22	22	22	22		0.3
	plane floor with bedding	8	8	8	8	6	6	6	6	5	5	5	5	5	5	5	5	5	4	4	4	4	5	5	5	0.3	0.4
	deep bedding	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1.0	0.4
	time spent on pastures (in % of year)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
weaners	fully slatted floor, slurry	45	45	45	45	57	57	57	57	62	62	63	64	64	65	66	67	68	68	69	70	71	71	71	71		0.3
	partly slatted floor, slurry	41	41	41	41	33	33	33	33	28	28	28	27	27	26	26	25	25	24	24	23	23	23	23	23		0.3
	plane floor with bedding	10	10	10	10	7	7	7	7	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	0.15	0.4
	deep bedding	4	4	4	4	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	0.2	0.4
	time spent on pastures (in % of year)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
sows	straw based	42	42	42	42	26	26	26	26	24	24	23	22	21	21	20	19	18	17	16	15	14	14	14	14	0.5	0.34
	slurry based	58	58	58	58	74	74	74	74	76	76	77	78	79	79	80	81	82	83	84	85	86	86	86	86		0.34
	time spent on pastures (in % of year)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
boars	straw based	32	32	32	32	23	23	23	23	21	21	21	20	20	19	19	18	18	17	16	16	15	15	15	15	0.5	0.34
	slurry based	68	68	68	68	77	77	77	77	79	79	79	80	80	81	81	82	82	83	84	84	85	85	85	85		0.34
	time spent on pastures (in % of year)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		

livestock category	housing type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	bedding material (straw) kg place a^{-1}	kg NH_3-N per kg N in excreta
laying hens	cages; ≥2010: small group housing systems	95	95	95	95	95	94	92	90	89	88	87	85	84	81	77	73	70	68	62	38	18	14	13	11		[a]
	floor management, aviary	4	4	4	4	4	5	5	7	7	7	7	7	7	9	12	14	15	17	22	45	63	64	64	64	0.5	[a]
	free range, organic farming	1	1	1	1	1	2	2	4	4	5	7	8	9	10	11	13	14	15	16	18	19	22	23	24	0.5	[a]
broilers	floor management	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	1.4	0.09
pullets	floor management	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.75	0.09
ducks	floor management	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	22	0.16
geese	floor management and free range	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		0.57. per kg TAN (UAN) in excreta
turkeys, female	floor management	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	10.3	0.22
turkeys, male	floor management	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	10.3	0.22

livestock category	housing type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	bedding material (straw) kg place d^{-1}	kg NH_3-N per kg TAN in excreta
horses	straw based system	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	8.0 / 5.0	0.22
	time spent on pastures (in % of year)	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21		
sheep without lambs	straw based system	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.4	0.22
	time spent on pastures (in % of year)	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55		
lambs	straw based system	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.16	0.22
	time spent on pastures (in % of year)	57	57	58	58	57	57	58	57	57	57	57	57	57	57	57	57	57	57	57	57	55	55	55	55		
goats	straw based system	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.4	0.22
	time spent on pastures (in % of year)	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34		

[a] cf. Table 411: Laying hens, housing-specific partial NH3 emission factors

Table 409: Frequency distributions of storage systems (in %); quantities of digested energy crops; and pertinent emission factors

livestock category	storage type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	NH_3-N EF for storage, kg NH_3-N per kg TAN in storage system	NH_3-N EF for storage, kg NH_3-N per kg TAN in storage system (leachate / urine)	N_2O EF for storage kg N_2O-N per kg N in storage system	N_2O EF for storage kg N_2O-N per kg N in storage system (leachate / urine)	CH_4 MCF for storage kg CH_4-C per kg C in storage system < 10 °C	maximum CH_4 producing capacity (Bo) m³ per kg CH_4
cattle, untreated slurry	open tank (% of total untreated slurry)	1	1	1	1	1	1	1	1	1	1	1	2	2	2	3	3	4	4	5	5	6	6	6	6	0.150		0.000		0.170	0.23
	solid cover (% of total untreated slurry)	19	19	19	19	18	18	18	18	18	18	19	20	21	22	23	24	25	26	27	28	29	29	29	29	0.015		0.005		0.170	0.23
	natural crust (% of total untreated slurry)	38	38	38	38	43	43	43	43	43	43	41	40	38	37	35	34	33	31	30	28	27	27	27	27	0.045		0.005		0.100	0.23
	plastic film (% of total untreated slurry)	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.023		0.000		0.170	0.23
	artificial crust (chaff) (% of total untreated slurry)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.030		0.000		0.170	0.23
	storage below animal confinements > 1 month (% of total untreated slurry)	42	42	42	42	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	0,045		0.002		0.170	0.23
cattle, digestion of slurry	% of total cattle slurry	0	0	0	0	0	0	0	0	0	0	1	1	1	1	2	4	6	9	11	13	17	21	23	23						
cattle, digestion of solid manure	% of total solid manure of cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	2	2	3	4	4	4						
cattle, storage of digestates	gas tight storage (% of digestates)	0	1	2	3	4	5	5	6	7	8	9	10	11	12	14	15	20	25	30	35	41	46	57	57	0.000		0.000		0.027	0.23
cattle, storage of digestates	open tank (% of digestates)	100	99	98	97	96	95	95	94	93	92	91	90	89	88	86	85	80	75	70	65	59	54	43	43	0.045		0.005		0.031	0.23

livestock category	storage type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	NH_3-N EF for storage, kg NH_3-N per kg TAN in storage system	NH_3-N EF for storage, kg NH_3-N per kg TAN in storage system (leachate / urine)	N_2O EF for storage kg N_2O-N per kg N in storage system	N_2O EF for storage kg N_2O-N per kg N in storage system (leachate / urine)	CH_4 MCF for storage kg CH_4-C per kg C in storage system < 10 °C	maximum CH_4 producing capacity (Bo) m³ per kg CH_4
dairy cattle, solid manure	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.600	0.013	0.013	0.005	0.020	0.23
male beef cattle, solid manure	heap (% of total solid manure)	42	42	42	42	39	39	39	39	38	38	30	27	25	23	22	22	21	21	20	20	20	20	20	20	0.600	0.013	0.013	0.005	0.020	0.23
	sloped floor (% of total solid manure)	58	58	58	58	61	61	61	61	62	62	70	73	75	77	78	78	79	79	80	80	80	80	80	80	0.600		0.010	0.005	0.170	0.23
heifers, solid manure	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.600	0.013	0.013	0.005	0.020	0.23
calves, solid manure	heap (% of total solid manure)	50	50	50	50	50	50	50	50	50	50	50	50	50	0	0	0	0	0	0	0	0	0	0	0	0,600	0,013	0.013	0.005	0.020	0.23
	deep bedding (% of total solid manure)	50	50	50	50	50	50	50	50	50	50	50	50	50	100	100	100	100	100	100	100	100	100	100	100	0.600		0.010		0.170	0.23
suckler cows, solid manure	heap (% of total solid manure)	7	7	7	7	7	7	7	7	6	6	7	9	10	11	13	14	15	17	18	20	21	21	21	21	0.600	0.013	0.013	0.005	0.020	0.23
	deep bedding (% of total solid manure)	93	93	93	93	93	93	93	93	94	94	93	91	90	89	87	86	85	83	82	80	79	79	79	79	0.600		0.010		0.170	0.23
mature males, solid	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.600	0.013	0.013	0.005	0.020	0.23
pigs, untreated slurry	open tank (% of total untreated slurry)	54	54	54	54	32	32	32	32	32	32	30	28	26	23	21	19	17	15	13	11	9	9	9	9	0.150		0.000		0.250	0.30
	solid cover (% of total untreated slurry)	20	20	20	20	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	0.015		0.005		0.250	0.30
	natural crust (% of total untreated slurry)	4	4	4	4	16	16	16	16	15	15	16	18	19	20	22	23	24	25	27	28	29	29	29	29	0.105		0.005		0.150	0.30
	plastic film (% of total untreated slurry)	0	0	0	0	7	7	7	7	7	7	7	6	5	5	4	3	3	2	1	1	0	0	0	0	0.023		0.000		0.250	0.30

livestock category	storage type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	NH_3-N EF for storage, kg NH_3-N per kg TAN in storage system	NH_3-N EF for storage, kg NH_3-N per kg TAN in storage system (leachate / urine)	N_2O EF for storage kg N_2O-N per kg N in storage system	N_2O EF for storage kg N_2O-N per kg N in storage system (leachate / urine)	CH_4 MCF for storage kg CH_4-C per kg C in storage system < 10 °C	maximum CH_4 producing capacity (Bo) m³ per kg CH_4
	artificial crust (chaff) (% of total untreated slurry)	0	0	0	0	1	1	1	1	1	1	1	1	2	2	2	3	3	3	3	4	4	4	4	4	0.030		0.000		0.250	0.30
	storage below animal confinements > 1 month (% of total untreated slurry)	37	37	37	37	37	37	37	37	38	38	37	36	36	35	35	34	34	33	32	32	31	31	31	31	0.105		0.002		0.250	0.30
pigs, digested slurry	% of total pig slurry	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	3	4	5	6	8	10	12	13	13						
pigs, storage of digestates	gas tight storage (% of digestates)	0	1	2	3	4	5	5	6	7	8	9	10	11	12	14	15	20	25	30	35	41	46	57	57	0.000		0.000		0.035	0.30
pigs, storage of digestates	open tank (% of digestates)	100	99	98	97	96	95	95	94	93	92	91	90	89	88	86	85	80	75	70	65	59	54	43	43	0.045		0.005		0.039	0.30
fattening pigs / weaners, solid manure	heap (% of total solid manure)	75	75	75	75	70	70	70	70	69	69	69	70	70	71	71	71	72	72	73	73	74	71	71	71	0.600	0.030	0.013	0.005	0.030	0.30
	deep bedding (% of total solid manure)	25	25	25	25	30	30	30	30	31	31	31	30	30	29	29	29	28	28	27	27	26	29	29	29	0.600		0.010		0.250	0.30
sows / boars, solid manure	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.600	0.030	0.013	0.005	0.030	0.30
laying hens	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.140		0.001		0.015	0.39
broilers	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.170		0.001		0.015	0.36
pullets	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.170		0.001		0.015	0.39
ducks	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.240		0.001		0.015	0.36

livestock category	storage type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	NH_3-N EF for storage, kg NH_3-N per kg TAN in storage system	NH_3-N EF for storage, kg NH_3-N per kg TAN in storage system (leachate / urine)	N_2O EF for storage kg N_2O-N per kg N in storage system	N_2O EF for storage kg N_2O-N per kg N in storage system (leachate / urine)	CH_4 MCF for storage kg CH_4-C per kg C in storage system < 10 °C	maximum CH_4 producing capacity (Bo) m³ per kg CH_4
geese	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.160		0.001		Tier 1 method	Tier 1 method
turkeys, female	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.240		0.001		0.015	0.360
turkeys, male	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.240		0.001		0.015	0.360
poultry, digested solid manure		0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	3	4	5	6	8	9	11	11	11						
poultry, storage of digestates	gas tight storage (% of digestates)	0	1	2	3	4	5	5	6	7	8	9	10	11	12	14	15	20	25	30	35	41	46	57	57	0.000		0.000		0.011	see animal-specific
poultry, storage of digestates	open tank (% of digestates)	100	99	98	97	96	95	95	94	93	92	91	90	89	88	86	85	80	75	70	65	59	54	43	43	0.045		0.005		0.016	values (above)
horses	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.350		0.013		0.02	0.30
sheep	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.280		0.013		0.02	0.19
goats	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.280		0.013		0.02	0.18
digestion of energy plants	amount of energy plants digestates (Tg fresh matter)	0.01	0.02	0.03	0.04	0.05	0.12	0.20	0.25	0.56	0.64	1.02	1.45	2.10	2.49	3.24	8.81	12.3	16.6	19.4	24.6	30.8	38.4	42.7	44.4						
	gas tight storage (% of digestates)	0	1	2	3	4	5	6	7	8	8	9	10	11	13	14	16	21	26	32	37	42	48	59	59	0.000		0.000		0.010	0.37
	open tank (% of digestates)	100	99	98	97	96	95	94	93	92	92	91	90	89	87	86	84	79	74	68	63	58	52	41	41	0.045		0.005		0.014	0.37

Table 410: Frequency distributions of application procedures (in %), and pertinent emission factors

livestock category	application type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	NH_3-N EF for application, kg NH_3-N per kg TAN applied
cattle, untreated slurry	broadcast, without incorporation	10	10	10	10	2	2	2	2	2	2	2	2	2	1	1	1	1	1	0	0	0	0	0	0	0.50
	broadcast, incorporation < 1 h	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	0.10
	broadcast, incorporation < 4h	0	0	0	0	2	2	2	2	2	2	3	3	4	5	6	7	7	8	9	10	11	11	18	18	0.26
	broadcast, incorporation < 6h	5	5	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.35
	broadcast, incorporation < 8h	0	0	0	0	0	0	0	0	0	0	1	1	2	2	3	3	4	4	5	5	6	6	0	0	0.40
	broadcast, incorporation < 12h	0	0	0	0	21	21	21	21	22	22	20	18	16	14	13	11	9	7	5	3	1	1	0	0	0.43
	broadcast, incorporation < 24h	32	32	32	32	9	9	9	9	9	9	8	8	7	6	5	4	3	3	2	1	0	0	0	0	0.46
	broadcast, incorporation < 48h	4	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.50
	broadcast, vegetation	0	0	0	0	0	0	0	0	0	0	1	3	4	6	7	9	10	12	13	15	16	16	16	16	0.50
	broadcast, grassland	44	44	44	44	42	42	42	42	41	41	41	41	42	42	42	42	43	43	43	43	44	44	44	44	0.60
	trailing hose, without incorporation	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0.46
	trailing hose, incorporation < 1 h	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	0.04
	trailing hose, incorporation < 4h	0	0	0	0	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	3	3	0.15
	trailing hose, incorporation < 6h	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.20
	trailing hose, incorporation < 8h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0.24
	trailing hose, incorporation < 12h	0	0	0	0	9	9	9	9	9	9	8	7	7	6	5	4	3	3	2	1	0	0	0	0	0.30
	trailing hose, incorporation < 24h	1	1	1	1	2	2	2	2	2	2	2	2	2	1	1	1	1	1	0	0	0	0	0	0	0.39
	trailing hose, incorporation < 48h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.46
	trailing hose, vegetation	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	2	3	3	3	4	4	4	4	4	0.35
	trailing hose, short vegetation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.50
	trailing hose, grassland	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	2	2	2	2	2	2	2	2	0.54
	trailing shoe	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	0.36
	injection (open slot)	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0.24
	grubber and injection	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	0.05
cattle, solid manure	**broadcast, without incorporation**	13	13	13	13	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0.90
	broadcast, incorporation < 1 h	6	6	6	6	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	0.09
	broadcast, incorporation < 4h	0	0	0	0	9	9	9	9	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	0.45
	broadcast, incorporation < 12h	10	10	10	10	28	28	28	28	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	0.81
	broadcast, incorporation < 24h	46	46	46	46	24	24	24	24	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	0.90
	broadcast, incorporation < 48h	7	7	7	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.90
	broadcast, vegetation/grassland	19	19	19	19	25	25	25	25	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	0.90

livestock category	application type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	NH_3-N EF for application, kg NH_3-N per kg TAN applied
pigs, untreated slurry	broadcast, without incorporation	7	7	7	7	4	4	4	4	4	4	4	3	3	3	2	2	1	1	1	0	0	0	0	0	0.25
	broadcast, incorporation < 1 h	4	4	4	4	8	8	8	8	8	8	8	8	7	7	7	7	7	6	6	6	6	6	6	6	0.04
	broadcast, incorporation < 4h	0	0	0	0	1	1	1	1	1	1	2	2	3	4	5	5	6	7	8	9	9	9	15	15	0.09
	broadcast, incorporation < 6h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.11
	broadcast, incorporation < 8h	0	0	0	0	0	0	0	0	0	0	0	1	1	2	2	3	3	4	4	4	5	5	0	0	0.13
	broadcast, incorporation < 12h	0	0	0	0	29	29	29	29	28	28	25	23	21	18	16	13	11	8	6	4	1	1	0	0	0.16
	broadcast, incorporation < 24h	50	50	50	50	4	4	4	4	4	4	3	3	3	2	2	2	1	1	1	0	0	0	0	0	0.21
	broadcast, incorporation < 48h	3	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25
	broadcast, vegetation	30	30	30	30	22	22	22	22	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	0.25
	broadcast, grassland	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	2	2	3	3	3	3	3	3	3	0.30
	trailing hose, without incorporation	0	0	0	0	2	2	2	2	2	2	2	2	2	1	1	1	1	1	0	0	0	0	0	0	0.18
	trailing hose, incorporation < 1 h	0	0	0	0	5	5	5	5	5	5	5	5	5	5	5	4	4	4	4	4	4	4	4	4	0.02
	trailing hose, incorporation < 4h	0	0	0	0	1	1	1	1	1	1	2	2	3	3	3	4	4	5	5	6	6	6	10	10	0.06
	trailing hose, incorporation < 6h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08
	trailing hose, incorporation < 8h	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	2	2	2	2	3	3	3	0	0	0.09
	trailing hose, incorporation < 12h	0	0	0	0	10	10	10	10	10	10	9	8	7	7	6	5	4	3	2	2	1	1	0	0	0.11
	trailing hose, incorporation < 24h	4	4	4	4	2	2	2	2	2	2	2	2	1	1	1	1	1	1	0	0	0	0	0	0	0.14
	trailing hose, incorporation < 48h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.17
	trailing hose, vegetation	0	0	0	0	0	0	0	0	0	0	3	5	8	11	13	16	19	21	24	27	29	29	29	29	0.13
	trailing hose, short vegetation	1	1	1	1	8	8	8	8	9	9	8	7	6	6	5	4	3	2	2	1	0	0	0	0	0.25
	trailing hose, grassland	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0.21
	trailing shoe	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	0.12
	injection (open slot)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0.06
	grubber and injection	0	0	0	0	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	0.03

livestock category	application type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	NH_3-N EF for application, kg NH_3-N per kg TAN applied
pigs, solid manure	broadcast, without incorporation	36	36	36	36	29	29	29	29	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	0.90
	broadcast, incorporation < 1 h	4	4	4	4	16	16	16	16	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	0.09
	broadcast, incorporation < 4h	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0.45
	broadcast, incorporation < 12h	0	0	0	0	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	0.81
	broadcast, incorporation < 24h	53	53	53	53	33	33	33	33	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	0.90
	broadcast, incorporation < 48h	8	8	8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.90
	broadcast, vegetation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.90
cattle and pigs, leachate	broadcast, without incorporation	50	50	50	50	50	50	50	50	50	50	45	41	36	32	27	23	18	14	9	5	0	0	0	0	0.20
	broadcast, incorporation < 1 h	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	2	2	2	2	3	3	3	3	3	0.02
	broadcast, incorporation < 4h	0	0	0	0	0	0	0	0	0	0	1	1	2	3	4	4	5	6	7	7	8	8	19	19	0.07
	broadcast, incorporation < 8h	0	0	0	0	0	0	0	0	0	0	1	1	2	3	4	4	5	6	6	7	8	8	0	0	0.12
	broadcast, incorporation < 12h	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	2	2	2	2	3	3	3	0	0	0.14
	broadcast, vegetation	0	0	0	0	0	0	0	0	0	0	1	3	4	6	7	8	10	11	13	14	15	15	15	15	0.20
	broadcast, grassland	50	50	50	50	50	50	50	50	50	50	50	49	49	49	49	48	48	48	48	47	47	47	47	47	0.20
	trailing hose, without incorporation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.18
	trailing hose, incorporation < 1 h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0.01
	trailing hose, incorporation < 4h	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	2	2	4	4	0.05
	trailing hose, incorporation < 8h	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0.09
	trailing hose, incorporation < 12h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0.12
	trailing hose, vegetation	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	2	2	3	3	4	4	4	4	4	0.10
	trailing hose, grassland	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	2	2	2	2	3	3	3	3	3	0.14
	trailing shoe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0.08
	injection (open slot)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0.04
	grubber and injection	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	2	2	3	3	3	3	3	3	3	0.02
laying hens, solid manure	broadcast, without incorporation	8	8	8	8	5	5	5	5	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	0.90
	broadcast, incorporation < 1 h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
	broadcast, incorporation < 4h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.18
	broadcast, incorporation < 12h	0	0	0	0	11	11	11	11	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	0.40
	broadcast, incorporation < 24h	92	92	92	92	84	84	84	84	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	0.45
poultry, except laying hens, solid manure	broadcast, incorporation < 24 h	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.45
all other animals, solid manure *)	broadcast, without incorporation	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.90

livestock category	application type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	NH_3-N EF for application, kg NH_3-N per kg TAN applied
digested manure (cattle, pigs, poultry) and digested energy plants	broadcast, without incorporation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.50
	broadcast, incorporation < 1 h	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0.10
	broadcast, incorporation < 4h	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	16	16	0.26
	broadcast, incorporation < 8h	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	0	0	0.40
	broadcast, incorporation < 12h	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0.43
	broadcast, vegetation	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	0.50
	broadcast, grassland	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	0.60
	trailing hose, without incorporation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.46
	trailing hose, incorporation < 1 h	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0.04
	trailing hose, incorporation < 4h	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	13	13	0.15
	trailing hose, incorporation < 8h	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	0	0.24
	trailing hose, incorporation < 12h	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0.30
	trailing hose, vegetation	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0.35
	trailing hose, grassland	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0.54
	trailing shoe	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	0.36
	injection (open slot)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	0.24
	grubber and injection	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	0.05

*) horses, sheep, goats

Table 411: Laying hens, housing-specific partial NH_3 emission factors

[in kg NH_3-N per excreted kg N]	≤ 2000	2001 - 2009	≥2010
cage housing; as of 2010: small-group housing	0.164		0.066
floor management, aviary	0.351	linear interpolation	0.090
intensive outdoor management, free-range management, organic production		0.099	

19.4 Other detailed methodological descriptions for the source/sink category "Land-use change and forestry" (4)

19.4.1 Land-use matrix

19.4.1.1 Justification of the decision in favour of a sample-based system

Germany has a range of spatially explicit data available for annual determination of land-use changes. Each of the different sets of data involved has specific advantages and disadvantages, in terms of such aspects as:

- Periodic vs. annual surveys
- Regional surveys vs. national, complete surveys
- Surveys with complete area coverage vs. incomplete surveys with gaps (with incompleteness system-based)
- Focus on surveying (actual) states vs. focus on surveying changes
- Detection of only a single land-use category (such as Forest land)

Owing to the aforementioned differences between sets of data, the following questions arise in connection with any further use of data:

- Do the data take adequate account of all types of land use?
- In their definitions of land-use and land-use-change classes, do the different data records agree among themselves – and with national or international definitions?
- Are the data updated?
- Do their underlying survey methods continue to improve?
- Are any new sources of information available, etc.?

In many cases, development and establishment of GIS-based map systems that are both substantially comprehensive and spatially explicit and complete did not begin until the 1990s. Gradually, the available database was built, and its quality was successively improved. As a result, information about land uses in 1990 – or in periods before or after that year – is not available for every area and every sample point. For that reason, a flexible system has been developed that draws information from the greatest possible number of data sources, for the following purposes:

- Obtaining comprehensive and complete land-use-change information,
- Taking account of the qualitative differences between the different data sources,
- Taking account of the spatial and qualitative development of the data,
- Verifying changes shown via comparison of different data sources,
- Ensuring that the definitions of land-use categories in the time series are consistent, and
- Allowing additional (own) research.

In light of the data available in Germany, only a sample-based system can achieve these purposes, since such a system

- Can verify data sources,
- Can quantify different error sources,
- Considers changes on a point-wise basis, rather than on an area-wise basis. For these reasons, a sample-based system

- is more robust in handling minor degrees of imprecision, in area-boundary delimitation, that result from differences between different data sources, and
- does not need to provide 100% accuracy in georeferencing (FULLER 2003).
- Can verify the plausibility of land-use changes, and
- Can integrate data sources that are available only in sample form, meaning that the database can be expanded.

The National Forest Inventory (Bundeswaldinventur – BWI) is such a sample-based system. In place since 1987, it periodically, and very precisely, surveys land-use changes from and to forest land. The BWI network is now being used systematically for determination of all land-use changes. In addition to providing consistency in area calculations, that system achieves full consistency between reporting under the UN Framework Convention on Climate Change and reporting within the framework of Article 3.3/3.4 of the Kyoto Protocol. In May 2011, Germany's decision in favour of a sample-based system was approved by a national workshop for experts. Subsequently, it was presented and discussed in the context of an international workshop for experts. The international experts who took part in that event found the system to be well-suited for current and future use.

19.4.1.2 Justification of the decision in favour of the BWI grid

Some of the 31 LULUCF classes (main land-use classes with no changes to "Other Land") account for very small total areas in Germany. For that reason, a simulation was carried out to determine whether such areas can be surveyed precisely enough with the current nation-wide basic 4km x 4km grid, and with the current (state-) Land-specific higher-resolution 2km x 2km grid areas, or whether the resolution of the BWI network needs to be further increased. To that end, a systematic, simple sampling network with 100m x 100m grid cells was generated. From that network, up to 25 sub-networks were derived for each of the following grid cell sizes: 200m x 200m, 500m x 500m, 1,000m x 1,000m and 2,000m x 2,000m. From a statistical perspective, it is desirable for each of the 31 LULUCF classes to be covered if at all possible. At the same time, no requirement has been imposed to the effect that estimates of the area shares of even the smallest LULUCF classes have to differ significantly from zero. The test results indicate that a 1km x 1km network has the optimal resolution. If one ignores the manner in which the 217,603 BWI cluster points used nationwide are arranged into clusters and higher-resolution areas, then each cluster point represents an area of 1.644km^2 which, in a quadratic arrangement, about corresponds to a network density of 1,280m x 1,280m. From a statistical perspective, the decision in favour of the current BWI 2012 network thus represents a good compromise. The number of sample points actually used is near to the number that one would have with a systematic 1km x 1km network. Since the correlation between the cluster points is smaller than 1, the probability increases that a single cluster will cover several land-use-change classes, and this also applies to clusters covering land-use-change classes with very small area shares. At the same time, the number of extremely small sampling elements is smaller with a cluster sample than it is with a simple sample, if the same number of sample points is used in each case. The sampling error thus has been conservatively estimated.

In light of requirements pertaining to reporting, the BWI 2012 network can be considered optimal, since:

- an internally consistent land-use matrix can be prepared only with the BWI network,
- including a matrix that is consistent with the BWI forest-area estimates,
- and is consistent with the BWI carbon- stock-change estimates.

The approach thus fulfills the stringent quality criteria required especially in the KP-reporting context.

19.4.2 Determination of emission factors for mineral soils

The following data sources provide the basis for determination of the mean carbon stocks in mineral soils, weighted by climate region, and considered from a complete-coverage perspective, as a function of land use:

1. Soil-overview map (Bodenübersichtskarte; BÜK), scaled to 1:1,000,000 (BÜK 1000; BGR 1995, 1997, Düwel et al. 2007)
2. Estimator profiles from the BÜK 1000 n 2.3; FISBo BGR (BGR 2011)
3. "Gehalte an organischer Substanz in Oberböden Deutschlands – Bericht über länderübergreifende Auswertung von Punktinformationen im FISBo BGR" ("Concentrations of organic matter in Germany's topsoils – report on Länder-overarching evaluation of point data in the FISBo BGR") (DÜWEL et al. 2007)
4. Results of the Forest Soil Inventory II (BZE II; vTI 2011)
5. Data records of the Basic Digital Landscape Model (Basis-Digitalen Landschaftsmodell; B-DLM) of the ATKIS® official topographic-cartographic information system, for the years 2000, 2005, 2010 (AdV 2000; 2005; 2010)
6. IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4 - Agriculture, Forestry and Other Land Use (IPCC 2006)

The emission factors for the various land-use categories were determined with the help of a fallback system. This means that

- where specifically collected soil data are available for a given land-use category (BZE II data; data from the BGR study (DÜWEL et al. 2007)), those data have been used, either by themselves or in combination with data from the BÜK 1000, for determination of the soil carbon stocks in the relevant categories.
- Where such data are not available, determination has been based on estimates from the BÜK 1000.

In keeping with the different data situations for the various land-use categories, the area-weighted, use-specific and soil-specific carbon stocks were determined separately for the various categories.

19.4.2.1 Forest Land

The mean value, as determined in Forest Soil Inventory II (BZE II), for carbon stocks in mineral soils, to a soil depth of 30 cm, was assigned to areas that the National Forest Inventory has declared to be "forest land", within the meaning of the definition of the Federal Forest Act and of Germany's choice of IPCC definition of "forest land".

The BZE II, a systematic sampling survey, was carried out for the purpose of collecting basic information about the condition of forest soils and the changes taking place in them. Its aims included collecting data on key soil characteristics. To that end, the various Länder intensively studied the soil and site characteristics at a total of some 2,000 points distributed throughout a complete-coverage 8 x 8 km grid. The effort was carried out in accordance with standardised work instructions that had been developed and defined via a cooperative effort of the Federal Government and the Länder (cf. Chapters 6.4.2.1.2 and 6.4.2.5).

Upon being completed, the work made it possible to base LULUCF inventory calculations, as of the 2013 Submission, on the final results of the Forest Soil Inventory II (BZE II) relative to soil carbon stocks and their rate of change. That survey found the mean carbon stocks for mineral soils, to a depth of 30 cm, to be 61.8 ± 3.7 Mg ha^{-1} for the year 2006. The mean annual rate of change determined for the period between the two soil inventories amounts to 0.41 ± 0.22 Mg ha^{-1} a^{-1} (cf. Chapter 6.4.2.1.2). To determine the carbon stocks of forest mineral soils for the various years covered by the report, the mean rate of change was added to / deducted from the average mineral-soil carbon stocks for all of Germany's forest soils determined for the year 2006. This yielded the following time series for the report period beginning in 1990 (Table 412):

Table 412: Mean carbon stocks [to 30 cm soil depth, in MgC ha^{-1} ± 1.96 * standard error] in Germany's mineral forest soils, 1990 – 2013

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
$C_{stocks\_forest\ soil}$	55.65 ± 6.26	56.06 ± 6.31	56.47 ± 6.35	56.47 ± 6.35	56.88 ± 6.40	57.29 ± 6.45	57.70 ± 6.49	58.11 ± 6.54	58.52 ± 6.58	58.93 ± 6.63	59.34 ± 6.68
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
$C_{stocks\_forest\ soil}$	59.75 ± 6.72	60.16 ± 6.77	60.57 ± 6.81	60.98 ± 6.86	61.39 ± 6.91	61.80 ± 6.95	62.21 ± 7.00	62.62 ± 7.04	63.03 ± 7.09	63.44 ± 7.14	63.85 ± 7.18
	2012	**2013**									
$C_{stocks\_forest\ soil}$	64.26 ± 7.23	64.67 ± 7.28									

In each case, the value shown for a year serves as the basis for all relevant calculations in the framework of inventory preparation.

19.4.2.2 The land-use categories cropland, grassland, wetlands, settlements and other land

19.4.2.2.1 General information relative to 4.B - 4.F

The BÜK 1000 soil overview map divides Germany's soils into 71 different characteristic soil categories / legend units. Those units, known as "dominant soil associations" (DSA), comprise dominant and secondary soil types. They are characterised on the basis of dominant soil types that are representative for the areas in question and that have been assigned selected soil profiles. Along with descriptive parameters, the profile descriptions include information about key soil characteristics, such as humus and nitrogen content and physical soil parameters (DÜWEL et al. 2007). For example, the data set on which the present calculations are based includes derived specific measurements for carbon (C_t), inorganic carbon (C_i), nitrogen (N_t), rock content and raw $density_{dry}$, as well as ranges for those values, in the form of class information pursuant to Germany's KA4 soil mapping instructions (AG BODEN 1994).

The mean carbon stocks of a dominant soil association can be calculated from these data by multiplying the carbon content by soil mass and correcting for skeleton and carbonate content. For determination of the mean carbon stocks in mineral soils of the categories cropland, grassland, wetlands, settlements and other land, the BÜK 1000 was merged with the Basis-DLM (Chapter 6.3.1.2). The use-specific area data and soil-characteristics data of the BÜK 1000 (bulk density, skeleton content) were combined with the organic-carbon data produced by the BGR study "Gehalte organischer Substanz in Oberböden Deutschlands: Länderübergreifende Auswertung von Punktinformationen im FISBo BGR" ("Concentrations of organic matter in Germany's topsoils – report on Länder-overarching evaluation of point data in the BGR's soil information system") (DÜWEL et al. 2007).

DÜWEL et al. 2007 list typical concentrations of organic matter (C_{org}) and humus in Germany's topsoils, for a total of 15 groups of soil parent material and 4 climate zones. Those listings are based on complete-coverage evaluation of data for ca. 14,000 profiles, broken down by use (cropland, grassland and forest) and by climate region.

In addition, that study assigns the 71 legend units of the BÜK, on the basis of their pedo-lithological characteristics, to those 15 groups of soil parent material (DÜWEL et al. 2007), with the result that those groups serve as links to the legend-unit information of the BÜK 1000.

19.4.2.2.2 Cropland

Cropland with annual crops

For cropland with annual crops, the BGR study asserts that its values are valid to a soil depth of 30 cm. As a result, it was possible to apply the carbon-content data from the BGR study to all dominant soil associations of the BÜK 1000.

Table 413: Area [ha], mean area-based carbon stocks [Mg C ha^{-1}] and pertinent uncertainties (upper and lower bounds in %) for croplands in Germany with annual crops

Mineral soils	Carbon stocks [Mg C ha^{-1}]	Bounds	
		upper [%]	lower [%]
Cropland_{annual}	59.77	50.07	32.67

Cropland with perennial crops

With regard to croplands with perennial crops (such as fruit trees, grapevines), it was assumed that such areas are not plowed and are covered to a degree of 75 % with grass. For that reason, calculations of mean carbon stocks for such areas were based on the profile characteristics for grassland. The relevant approach is described in Chapter 19.4.2.2.3. Table 414 shows the values obtained for such areas.

Table 414: Area [ha], mean area-based carbon stocks [Mg C ha^{-1}] and pertinent uncertainties (upper and lower bounds in %) for croplands in Germany with perennial crops

Mineral soils	Carbon stocks [Mg C ha^{-1}]	Bounds	
		upper [%]	lower [%]
Cropland with perennial crops	72.64	68.18	46.40

Carbon stocks for cropland

The mean carbon stocks for mineral soils in cropland are obtained as follows:

$$C_{\min\_cropland} = \frac{\left(C_{cropl.\ annual} * A_{cropl.\ annual} + C_{cropl.\ perennial} * A_{cropl.\ perennial}\right)}{A_{cropl.\ annual} + A_{cropl.\ perennial}}$$

$C_{min\_cropland}$: Mean area-related carbon stocks for all of Germany's mineral cropland soils [Mg ha^{-1}]

$C_{cropland\_annual}$: Mean area-related carbon stocks for all of Germany's mineral cropland soils with annual crops [Mg ha^{-1}]

$C_{cropland\_perennial}$: Mean area-related carbon stocks for all of Germany's mineral cropland soils with perennial crops [Mg ha^{-1}]

$A_{cropland\_annual}$: Area of mineral-soil lands in Germany under cropland with annual crops [ha]

$A_{cropland\_perennial}$: Area of mineral-soil lands in Germany under cropland with perennial crops [ha]

Table 415 shows the mean carbon stocks, for mineral soils under cropland, that have been used as a basis for all pertinent calculations within the inventory.

Table 415: Mean area-based carbon stocks [Mg C ha^{-1}] and pertinent uncertainties (upper and lower bounds in %) for croplands in Germany

Mineral soils	Carbon stocks [Mg C ha^{-1}]	Bounds upper [%]	lower [%]	Distribution function
Cropland	60.03	50.50	32.99	Log-normal

19.4.2.2.3 Grassland

The land-use category "grassland" comprises the sub-categories "grassland in a strict sense" and "woody grassland" (cf. Chapter 6.3). Calculations for both sub-categories are carried out on the basis of the same data. The differences between the carbon stocks of these sub-categories thus result only from differences in spatial distribution of land uses and, thus, differences in percentage shares of soil-parent-material groups and climate zones.

For grassland areas, the BGR study asserts that its values are valid to a depth of 10 cm (DÜWEL et al. 2007). The soil carbon stocks were correlated with the characteristics of the mineral-soil profiles of the BÜK 1000 via relationships with soil-parent-material groups, as follows: The soil-carbon-stocks data of the BGR study (DÜWEL et al. 2007) were assigned to the uppermost horizon, in keeping with the thickness as listed (maximum thickness of 10 cm). For that horizon, the bulk density and the skeleton content were taken from the BÜK 1000, as were the data for all characteristics and thicknesses of deeper horizons and depth layers, to a depth of 30 cm. The relevant results are shown in Table 416.

Table 416: Mean area-based carbon stocks [Mg C ha^{-1}] and pertinent uncertainties (upper and lower bounds in %) for grasslands in Germany

Mineral soils	Carbon stocks [Mg C ha^{-1}]	Bounds upper [%]	lower [%]	Distribution function
Grassland in a strict sense	77.43	77.87	45.93	Log-normal
Woody grassland	73.18	83.27	42.94	Log-normal

19.4.2.2.4 Terrestrial wetlands, settlements and other land

The mean carbon stocks of mineral soils in terrestrial wetlands (the "wetlands" category is subdivided into terrestrial wetlands and waters) were determined via a procedure similar to that used for grassland. Consequently, the procedure is described in Chapter 19.4.2.2.3. Differences in carbon stocks, between grassland and terrestrial wetlands, result solely from differences in spatial distribution of category areas.

The database on which the BÜK 1000 (Soil map for the Federal Republic of Germany 1:1,000,000) is based lists no dominant profiles for soils on settlement areas and other land; it lists such profiles only for forest, cropland and grassland locations. Dominant profiles are not available for all dominant soil associations for those latter three uses, however. For this reason, the profiles for grassland locations were used as substitute dominant profiles for soils in settlement and other-land locations (due to grassland soils' relative similarity to soils in gardens and parks). For those dominant soil associations for which no dominant grassland profiles, with key pedological data, were available, the horizons seen in forest-soil profiles were used, since settlement soils – and, especially, soils in "other land" areas – are often disturbed and, in their topsoils, lack the deeply developed A horizons that agriculturally cultivated grasslands or croplands have. For a total of 42 of the 71 dominant soil profiles, this approach leads to changes in – and, in most cases, reductions of – carbon stocks in comparison with grassland.

In addition, the spatial distribution of settlement areas and other land in the soil landscape has a clear influence on the mean carbon stocks of mineral soils – on mineral soils' stocks with respect to grassland soils, and on these categories' (4.E and 4.F) mineral-soil stocks with respect to each other.

The mean carbon-stocks values are listed in Table 417.

Table 417: Mean area-based carbon stocks [Mg C ha^{-1}], and pertinent uncertainties (upper and lower bounds in %), in mineral soils under terrestrial wetlands, settlements and other land

Mineral soils	Carbon stocks [Mg C ha^{-1}]	Bounds		Distribution function
		upper [%]	lower [%]	
Terrestrial wetlands	73.99	52.48	43.85	Log-normal
Settlements	58.67	84.97	45.11	Log-normal
Other land	55.60	92.86	44.56	Log-normal

The emission factors derived from these mean carbon stocks, which are weighted by climate region, land use and areas, are listed in Table 258 and Table 259 in Chapter 6.1.2.1 . The emission factors are listed with statistical indexes, for description of uncertainties, in Table 317 and Table 322 in Chapters 6.7.3 and 6.8.3.

19.4.2.2.5 Uncertainties

Since individual profiles do not support conclusions relative to the heterogeneity of soil parameters within the legend units (DÜWEL et al. 2007), relevant extreme constellations of class values were constructed for purposes of estimating the potential ranges of carbon and nitrogen stocks in dominant soil associations (DSA) – and, thus, for purposes of determining the relevant uncertainties:

DSA carbon stocks$_{maximum}$: C$_{org}$ content$_{maximum}$, bulk density$_{maximum}$, skeleton content$_{minimum}$

DSA carbon stocks$_{minimum}$: C$_{org}$ content$_{minimum}$, bulk density$_{minimum}$, skeleton content$_{maximum}$

The values for bulk density, skeleton content and carbon stocks in horizons for which no corresponding values were available from the topsoil study of the BGR (DÜWEL et al. 2007) were derived, with the help of KA 4, in accordance with pertinent class information from the dominant-profile descriptions in the BÜK 1000 (BGR 1997).

The so-determined minimum and maximum carbon stocks form the relevant upper and lower boundaries and, in combination with the location scale, show the typical steep-left distribution that is typical for such data.

The carbon-stocks data from the BGR study (DÜWEL et al. 2007) are backed by descriptive statistics. The values for the 25th and 75th percentiles, i.e. the upper and lower threshold values for the carbon stocks, were derived from those statistics.

19.4.2.3 Planned improvements

The values listed in the above chapters are the best data now available in complete-coverage form. Major inventories for determination of the carbon and nitrogen stocks in mineral soils have been carried out, and are being carried out, in Germany, with a view to improving such data:

- The Forest Soil Inventory II (BZE II Wald), for all forest soils – the results of which have been used as of the 2013 Submission;

- The Agricultural Soil Inventory (Bodenzustandserhebung Landwirtschaft), for cropland and grassland soils (cf. Chapter 6.5.6)
- The results of the Agricultural Soil Inventory are being used for step-by-step validation of the current emission factors. Complete implementation of the results, as a basis for reporting on mineral soils, is not expected prior to 2019.

Chapter 10.2, Inventory Improvements (Table 341), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 340 in the same chapter.

19.4.3 Derivation of calculation figures (emission factors) for biomass

19.4.3.1 Perennial crops

In the framework of the research project "Development of methods for determining the biomass of plants, outside of forests, with multiple years of wood growth" ("Methodenentwicklung zur Erfassung der Biomasse mehrjährig verholzter Pflanzen außerhalb von Waldflächen"), country-specific carbon-stock data were collected for the above-ground and below-ground biomass of orchards, vineyards and Christmas-tree plantations in Germany. The mean carbon stocks of the plants in tree nurseries were then estimated on the basis of these data, and of results of the National Forest Inventory. Mean tree biomass values for short-rotation plantations were derived from literature data, on a country-specific basis.

19.4.3.1.1 Fruit trees

In the framework of the above-mentioned research project, a total of 100 fruit trees (91 apple trees, 6 cherry trees and 3 plum trees) of different ages and varieties, from Germany's two main fruit-cultivation regions ("Altes Land" in northern Germany and the Lake Constance region in southern Germany), were destructively tested. In addition, the following data was collected from 210 living apple trees:

- diameter at stem base
- diameter at breast height
- height

A regression procedure applied to all collected data yielded a highly significant link between tree age and mean stem diameter (=(diameter at stem base + diameter at breast height)/2):

Equation 50: Regression equation for estimating mean stem diameter [cm] of apple trees, as a function of tree age [a]

$$S_{mean\ Apfel} = 14{,}2986 * \left(1 - e^{(-0{,}0528x)}\right)$$

S_{mean_apple}: Mean stem diameter, apple tree [cm]
x: Tree age [a]
Statistical indexes / uncertainties:
$r^2 = 0.9486$
$p < 0.0002$
Standard error of estimation = 0.5225 ≙ 8.44 %

The total uncertainty in the estimation of the mean stem diameter of apple trees as a function of tree age amounts to 23.59 % (half of the 95 % confidence interval).

Equation 51: Regression equation for estimating mean stem diameter [cm] of cherry and plum trees, as a function of tree age [a]

$$S_{mean\ cherry/plum} = 53.8165 * \left(1 - e^{(-0.0252x)}\right)$$

$S_{mean\_cherryplum}$: Mean stem diameter, cherry/plum tree [cm]
x: Tree age [a]
Statistical indexes:
r^2 =0.9486
n = 9
p < 0.0001
Standard error of estimation = 1.2963 ≙ 11.14 %

The estimation of the stem diameter of cherry and plum trees as a function of tree age is subject to a total uncertainty of 25.68 % (half of the 95 % confidence interval).

Via destructive testing, the masses, water content and carbon content of the fruit trees were separately determined for the compartments above-ground biomass (trunk and branches) and below-ground biomass (roots). The ages of the so-tested apple trees were 6 and 9, while the ages of the cherry and plum trees were 4, 12 and 14.

The trees' biomasses were adjusted to take account for the water content measured during drying at 105°C and then, to determine the carbon stocks of the trees' parts / whole trees, were multiplied by the carbon-content percentage of the $biomass_{dry}$.

From the resulting data, highly significant relationships were derived between mean stem diameter and carbon stocks of the entire plant (Equation 54, cherry/plum) and above-ground biomass (Equation 52, apple; Equation 55, cherry/plum). The carbon stocks in the below-ground biomass of cherry and plum trees was determined by subtracting the above-ground biomass from the total stocks, while the relevant stocks for apple trees were determined via the equation of MOKANY et al. (2006) (Equation 53). In a survey, they derived, for numerous types of vegetation, root / shoot ratios as a function of biomass, climatic parameters and local site parameters. Their results were then adopted as default values in the 2006 IPCC Guidelines (IPCC 2006).

Equation 52: Regression equation for estimating carbon stocks in the above-ground biomass of apple trees, as a function of mean stem diameter

$$\ln C_{above\ Apfel} = -2{,}7521 + 1{,}9533 * \ln x$$

ln C_{above_apple}: Logarithm for carbon stocks in above-ground plant parts [kg $plant^{-1}$]
ln x: Logarithm for mean stem diameter [cm]
Statistical indexes:
r^2 =0.8273
n = 90
p < 0.0001
Standard error of estimation = 0.044 ≙ 2.83 %

Equation 53: Regression equation for estimation of the carbon stocks in below-ground biomass of apple trees as a function of above-ground biomass (MOKANY et al. (2006)):

$$C_{below\ Apfel} = 0{,}489 * x^{0{,}89}$$

C_{below_apple}: Carbon stocks in below-ground plant parts [kg $plant^{-1}$]
x: Carbon stocks in above-ground biomass [kg $plant^{-1}$]
Statistical indexes:
r^2 =0.93
n = 301
Standard error of the estimation = 13.6 % (derived from MOKANY et al. (2006))

Equation 54: Regression equation for estimating carbon stocks of the entire biomass of cherry and plum trees, as a function of mean stem diameter

$$C_{total\ cherry\ /\ plum} = 0.0369\ x^{2.2725}$$

$C_{total\_cherryplum}$: Carbon stocks of entire cherry/plum tree biomass [kg plant^{-1}]
x: Mean stem diameter, cherry/plum tree [cm]
Statistical indexes:
r^2 =0.9608
n = 9
p < 0.0001
Standard error of estimation = 1.7382 ≙ 14.04 %

Equation 55: Regression equation for estimating carbon stocks in the above-ground biomass of cherry and plum trees, as a function of mean stem diameter

$$C_{above\ cherry\ /\ plum} = 0.0238\ x^{2.3586}$$

$C_{above\_cherryplum}$: Carbon stocks of above-ground cherry/plum tree biomass [kg plant^{-1}]
x: Mean stem diameter, cherry/plum tree [cm]
Statistical indexes:
r^2 =0.9442
n = 9
p < 0.0001
Standard error of estimation = 2.025 ≙ 18.76 %

The root C stocks of cherry / plum trees are obtained as the difference between the carbon stocks of the entire plant and the stocks of its above-ground parts (cf. Equation 56).

Equation 56: Estimation of the carbon stocks in the root mass of fruit trees of the same variety

$$C_{below} = C_{total} - C_{above}$$

C_{below}: Below-ground carbon stocks [kg plant^{-1}]
C_{total}: Carbon stocks of entire plant [kg plant^{-1}]
C_{above}: Above-ground carbon stocks [kg plant^{-1}]

The absolute C stocks of all fruit trees in Germany were calculated on the basis of the results of the last exhaustive statistical survey for the fruit cultivation sector. Such surveys were carried out in the years 2002, 2007 and 2012 (STATISTISCHES BUNDESAMT, various years). On the basis of that survey's results, the Federal Statistical Office determined total numbers of apple, pear, sweet cherry / sour cherry, plum / prune, mirabelle and greengage trees, in different age classes, as well as the areas under cultivation with trees in the various age classes. Examples of the pertinent results, for the year 2007, are shown in Table 418.

Table 418: Results of the exhaustive statistical survey of fruit trees carried out in 2007 by the Federal Statistical Office (2007)

Age class		Fruit trees, total	Apple	Pear	Sweet cherry	Sour cherry	Plum, prune	Mirabelle, greengage
1	Area [ha]	6,337	2,610	558	1,669	569	561	89
	Number [n]	77,908,784	1,959,650	374,357	349,898	309,888	174,950	25,268
1-4	Area [ha]	1,314	1,283	30	125	9	142	8
	Number [n]	3,493,397	3,460,242	51,926	92,723	6,720	98,538	4,372
5-9	Area [ha]	7,403	5,159	252	859	330	713	90
	Number [n]	15,410,632	13,645,705	466,895	563,239	234,410	452,011	48,372
10-14	Area [ha]	10,606	7,275	350	783	866	1,186	146
	Number [n]	19,740,123	17,334,084	581,720	458,483	579,748	722,909	63,179
15-19	Area [ha]	10,321	7,603	454	763	372	1,057	71
	Number [n]	19,602,081	17,527,552	831,342	322,364	260,231	632,286	28,306
20-24	Area [ha]	8,599	5,995	338	764	791	621	91
	Number [n]	12,899,071	11,365,689	443,150	219,989	543,127	290,899	36,217
>25	Area [ha]	3,333	1,837	119	519	507	284	66

Number [n]	3,348,345	2,569,271	126,438	143,442	351,826	130,916	26,452

To determine the total carbon stocks in fruit trees, the carbon stocks – either measured or determined via regression – in the above-ground and below-ground biomass of individual trees of each age class were multiplied by the relevant total numbers of trees. In the process, the values obtained for apple trees were also assigned to pear trees, while those obtained for cherry and plum trees were also assigned to prune, mirabelle and greengage trees.

The area-related emission factors for the various tree varieties were calculated, in each case, via division by the relevant area under cultivation.

Table 419: Area-related carbon stocks [Mg C ha^{-1}] (range, or ± half of the 95 % confidence interval) in the biomass of Germany's fruit trees

Fruit-tree survey, 2002				
Fruit tree	**Carbon stocks [Mg C ha^{-1}]**			**Area [ha]**
	Bio_{above}	**Bio_{below}**	**Bio_{total}**	
Apple	3.53 ± 0.85	1.55 ± 0.56	5.08 ± 2.20	32,406
Pear	2.93 ± 0.71	1.24 ± 0.45	4.18 ± 1.81	2,189
Sweet cherry	7.53 ± 1.39	1.33 ± 0.15	8.86 ± 1.25	5,505
Sour cherry	14.08 ± 2.74	2.67 ± 0.32	16.74 ± 2.5	4,230
Plum/prune	6.52 ± 1.36	1.28 ± 0.16	7.79 ± 1.25	4,562
Mirabelle/greengage	6.70 ± 1.26	1.25 ± 0.14	7.95 ± 1.14	473
Fruit-tree survey, 2007	Carbon stocks [Mg C ha^{-1}]			
Fruit tree	**Bio_{above}**	**Bio_{below}**	**Bio_{total}**	**Area [ha]**
Apple	4.56 ± 1.10	1.97 ± 0.71	6.53 ± 2.83	31,762
Pear	3.95 ± 0.95	1.66 ± 0.60	5.61 ± 2.43	2,101
Sweet cherry	7.71 ± 1.50	1.39 ± 0.17	9.09 ± 1.36	5,482
Sour cherry	15.24 ± 2.98	2.83 ± 0.34	18.07 ± 2.71	3,444
Plum/prune	7.71 ± 1.59	1.53 ± 0.19	9.24 ± 1.47	4,565
Mirabelle/greengage	7.28 ± 1.41	1.38 ± 0.16	8.66 ± 1.29	561
Fruit-tree survey, 2012	Carbon stocks [Mg C ha^{-1}]			
Fruit tree	**Bio_{above}**	**Bio_{below}**	**Bio_{total}**	**Area [ha]**
Apple	5.31 ± 1.28	2.27 ± 0.82	7.58 ± 3.29	31,739
Pear	4.91 ± 1.19	2.04 ± 0.73	6.95 ± 3.02	1.933
Sweet cherry	8.44 ± 1.65	1.57 ± 0.19	10.01 ± 1.49	5,258
Sour cherry	17.31 ± 3.53	3.13 ± 0.39	20.45 ± 3.19	2,292
Plum/prune	9.60 ± 1.93	1.9 ± 0.24	11.51 ± 1.78	3,870
Mirabelle/greengage	8.25 ± 1.62	1.51 ± 0.18	9.76 ± 1.47	501

19.4.3.1.2 Christmas-tree plantations

In 2013 in Germany, Christmas trees were cultivated on a total of 15,800 ha of agricultural land outside of forests (STATISTISCHES BUNDESAMT, 2014). With an average planting density of 6,000 plants per ha, a total of 50 Mg of dry biomass are produced (PÖPKEN 2011). Of that quantity, 28 % is root mass. That value was derived via the regression of root biomass as a function of above-ground biomass (Equation 53) pursuant to MOKANY et al. (2006) (cf. Chapter 19.4.3.1.1).

Table 420: Area-related carbon stocks [Mg ha^{-1}] (± half of the 95 % confidence interval) of biomass of Germany's Christmas trees (in plantations)

Tree	**Carbon stocks [Mg C ha^{-1}]**			**Area, 2013 [ha]**
	Bio_{above}	**Bio_{below}**	**Bio_{total}**	
Christmas trees	8.10 ± 4.1	3.15 ± 1.6	11.25 ± 4.4	15,800

19.4.3.1.3 Grapevines (wine)

In the project "Development of methods for determining the biomass of plants, outside of forests, with multiple years of wood growth" ("Methodenentwicklung zur Erfassung der Biomasse mehrjährig verholzter Pflanzen außerhalb von Waldflächen") (PÖPKEN 2011), a total of 74 grapevines were destructively tested for the purpose of deriving a country-specific mean value for carbon stocks of grapevines. The ages of the vines tested were 15 and 25 (years). In the testing, the vines' weights, and the water and carbon content of the above-ground and below-ground plant parts, were determined (PÖPKEN 2011). The carbon stocks of grapevines and of parts of vines are calculated via Equation 57.

Equation 57: Calculation of the carbon stocks in grapevines

$$C_{vine} = C_{cont\ above} * M_{105\ Bio\ above} + C_{cont\ below} * M_{105\ Bio\ below}$$

C_{vine}: Carbon stocks of one grapevine [kg]
$C_{cont\ above}$: Carbon content of the above-ground vine [by weight]
$M_{105\ bio\ above}$: Dry biomass of the vine [kg]
$C_{cont\ below}$: Carbon content of below-ground biomass [by weight]
$M_{105\ bio\ below}$: Dry biomass of below-ground biomass [kg]
$M_{cut\ fresh}$: Fresh weight of cut wood, per plant [kg]

The annual quantity of cut wood was not taken into account in determination of the biomass of grapevines, since the annual growth is basically the same as the quantity cut, and thus a temporary equilibrium occurs.

Since vineyards in Germany contain an average of 4,000 grapevines per ha (PÖPKEN 2011), the carbon stocks per area unit (ha) were calculated by multiplying the C stocks of individual plant compartments / total plants by 4,000. The absolute carbon stocks are calculated by multiplying the pertinent emission factors by the total vineyard area. The vineyard area figures are obtained from official German statistics (Statistisches Bundesamt, FS 3, R 3.1.5, various years). The resulting values are shown in Table 421.

Table 421: Area-related carbon stocks [Mg C ha^{-1}] (± half of the 95 % confidence interval) in grapevine biomass in Germany

Woody grassland	Carbon stocks [Mg C ha^{-1}]			Area, 2013 [ha]
	Bio_{above}	Bio_{below}	Bio_{total}	
Grapevines	1.12 ± 0.06	0.54 ± 0.04	1.66 ± 0.09	102,425

19.4.3.1.4 Short-rotation plantations

To obtain country-specific, mean carbon stocks in the biomass of short-rotation plantations, pertinent data were derived from the relevant literature. Key work in this regard included the overviews produced by WALTER et al. (2014), HORN (2013), GURGEL (2011), KERN et al. (2010), BIERTÜMPFEL et al. (2009), BOELCKE (2007), STOLZENBURG (2006) and MAIER & VETTER (2004).

This work includes the results obtained on 23 test sites, oriented to short-rotation plantations, distributed throughout Germany (Bavaria, Baden-Württemberg, Thuringia, Saxony, Brandenburg, Mecklenburg – West Pomerania and Lower Saxony). As a group, the sites covered all of the country's relevant climate zones (precipitation: 550 – 1550 mm), average annual temperatures 6.8 – 10.1°C), soil types (light to heavy soils) and geographic regions (lowlands to mid-elevation mountains). Short-rotation plantations were established on a total of 62 test areas. The main tree types included were poplars (58 %) and willow (34 %), although birch (3 %), alder, black locust (robinia) and foxglove tree (paulownia) (5%) were also planted. The rotation periods ranged from one to ten years, and averaged 4.2 years. Since these studies cover all relevant aspects of operation of short-rotation plantations in Germany, including spatial distribution, site conditions, vegetation and management practices, they are representative.

From the results of these studies, an average annual dry yield of 9.05 (-6.0 % / +9.9 %) Mg ha^{-1} a^{-1} of above-ground biomass was derived for short-rotation plantations in Germany.

The average total yield short-rotation plantations, as a function of plantation-operation duration, was obtained by multiplying the average annual dry yield by the number of years of plantation operation. An average plantation-operation duration of 20 years was assumed. In addition, it was assumed that the short-rotation plantations have even distributions throughout the various operational age classes (initialization class, and class1_a – class20_a). For the initialization phase, it was assumed that 10,000 cuttings, each with 20 g of biomass, were planted per hectare (≙ 0.2 Mg biomass ha^{-1}). The below-ground biomass was determined on the basis of the average dry yield, as a function of the operational duration and the formula provided by MOKANY et al. (2006). Via addition of above-ground and below-ground biomass, the total stocks in short-rotation plantations were determined for each different operational-age class. Via multiplication by 0.45, those stocks were then converted into carbon stocks. The average values of these carbon stocks, for all operational age classes, serve as the dynamic equilibrium values for the average, area-based carbon stocks in the biomass of short-rotation plantations, the values on which the pertinent inventory calculations are based. These values are shown in Table 422.

Table 422: Average, area-based carbon stocks [Mg C ha^{-1}] and 97.5 and 2.5% percentile values [%] in the biomass of short-rotation plantations

	Carbon stocks in the biomass of short-rotation plantations		
	Bio_{total}	**Bio_{above}**	**Bio_{below}**
C stocks [Mg C ha^{-1}]	**53.71**	**40.75**	**12.96**
97.5 percentile [%]	10.30	9.93	29.13
2.5 percentile [%]	8.16	6.02	28.04

19.4.3.1.5 Tree nurseries

In 2013, the total area occupied by tree nurseries in Germany amounted to 20,700 ha (STATISTISCHES BUNDESAMT 2014). An exhaustive tree-nursery survey carried out at 4-year intervals by the FEDERAL STATISTICAL OFFICE (STATISTISCHES BUNDESAMT, various years) provides information about the tree species cultivated in tree nurseries. The last such survey, carried out in 2012, showed that German tree nurseries cultivate primarily ornamental and other trees and shrubs (86.7 %); only 13.3 % of their area was used for cultivation of forest plants. The species composition of the cultivated trees and shrubs has varied widely over the years (STATISTISCHES BUNDESAMT 2013). Unfortunately, no studies have been carried out of the average biomass stocks in the trees and shrubs cultivated in tree nurseries in Germany. For this reason, the average carbon stocks per unit of tree-nursery area were derived from country-specific biomass-stock values for trees and shrubs. To this end, the following assumptions were made:

- Two-thirds of the trees and shrubs in tree nurseries are ornamental plants, and one-third are forest trees (this share was increased to 33 %, because although the recent survey showed that forest trees were being cultivated on only 13.3 % of the available area, that cultivation percentage has varied widely over the years (share of forest plants in 2004: 19.8 %, STATISTISCHES BUNDESAMT 2005), and ornamental-plant cultivation includes conifers (to a considerable extent) and "forest trees" such as oak and beech.
- The cultivation period for ornamental trees and shrubs is no more than 10 years, while that for forest plants is no more than 5 years.
- The age classes within the various tree/shrub groups are evenly distributed.

The carbon stocks determined via the project "Development of methods for determining the biomass of plants, outside of forests, with multiple years of wood growth" (PÖPKEN 2011) were also applied to ornamental trees and shrubs, in a representative approach. For half of the larger trees and shrubs, the carbon stocks determined for cherry and plum trees were applied; for half of the smaller trees and shrubs, the stocks determined for apple trees were used (cf. Chapter 19.4.3.1.1).

For calculation of the biomass of forest trees, the methods were used that were developed by KÄNDLER & BÖSCH (2013) for calculation of forest biomass. Those methods are described in Chapter 6.4.2.2. For spruce, pine, beech and oak, the above-ground biomass stocks per individual tree, up to a tree age of 5 years, were determined using Equation 18 and the coefficients shown in Table 260 (Chapter 6.4.2.2.4). The carbon-conversion factor 0.45 was used for conversion of units to Mg C ha^{-1} (cf. Chapter 6.4.2.2.4), and a total of 6,000 plants per ha was assumed (this corresponds to an average plant density, with a planting distance of about 120/130 cm). The below-ground biomass was estimated on the basis of the so-calculated shoot mass, using the formula of MOKANY et al. (2006) (cf. Chapter 18.4.3.1.1), while the total biomass stocks were obtained by adding the above-ground and below-ground stocks.

This derivation approach then yields, via determination of average values, the mean, area-based carbon stocks shown in Table 423 for the various trees and shrubs concerned, along with the resulting mean carbon stocks, which the inventory presents as the dynamic equilibrium values for the biomass in Germany's tree nurseries.

Table 423: Derivation of average area-based carbon stocks [mixed value for tree nurseries, in Mg C ha^{-1} ± half of the 95 % confidence interval] in the biomass of tree nurseries

Trees and shrubs	C stocks$_{total}$ [Mg C ha^{-1}]	C stocks$_{above}$ [Mg C ha^{-1}]	C stocks$_{below}$ [Mg C ha^{-1}]
Apple$_{10}$	6.69 ± 1.34	4.8 ± 1.16	1.89 ± 0.68
Cherry$_{10}$	21.52 ± 1.88	16.83 ± 1.92	4.69 ± 0.33
Forest trees$_{5}$	7.7 ± 0.82	5.54 ± 0.71	2.15 ± 0.42
Mixed value$_{tree\ nurseries}$	**11.97** ± 0.82	**9.06** ± 0.78	**2.91** ± 0.29

19.4.3.1.6 *Mean carbon stocks in the biomass of woody plants cultivated on cropland*

For calculation of the mean area-related carbon stocks in woody plants cultivated on cropland, the absolute carbon stocks of the various crop types were calculated, by compartments, summed and then divided by the relevant area. These calculations were carried out for the years 2002, 2007 and 2012 (Table 424). The intervals are tied to the survey dates for the fruit-tree census, which the Federal Statistical Office carries out only at five-year intervals. The census has been carried out in its current form only since 2002. The values between the individual surveys have been linearly interpolated. For the years 1990 – 2002, the data for the year 2002 have been used, while for the year 2013 the data for 2012 have been used. The latter set of data will be corrected via the next exhaustive survey, which is to take place in 2017.

Table 424: Determination of area-weighted carbon stocks [Mg C ha^{-1}] for woody plants cultivated on cropland in Germany, as of the years for the relevant statistical surveys (carbon stocks 2 ± half of the 95 % confidence interval)

Fruit trees	Carbon stocks [Mg C ha^{-1}]			ha
	Bio_{total}	Bio_{above}	Bio_{below}	Area
2002	5.04 ± 0.54	3.72 ± 0.38	1.31 ± 0.17	192,054
2007	5.19 ± 0.62	3.83 ± 0.39	1.36 ± 0.18	185,549
2012	6.52 ± 0.68	4.83 ± 0.42	1.70 ± 0.21	187,765

Since in Germany woody plants cultivated on cropland are always mixed with grass, the total biomass carbon stocks per area unit for such areas are calculated via Equation 58:

Equation 58:

$$C\ stocks_{cro2} = C\ stocks_{fruit\ trees} + biomass_{grassland} * 0.75$$

The factor for grassland biomass arises in that only the areas directly under the woody plants concerned are kept free of vegetative cover. In orchards and vineyards, grass grows only between rows of the cultivated woody plants. The value for grassland ("in a strict sense") is used as a basis for determining such biomass. Table 425 shows the time series for the biomass carbon stocks of perennial woody plants cultivated on cropland in Germany.

Table 425: Area-weighted mixed value for biomass carbon stocks [Mg C ha^{-1}] of perennial woody plants cultivated on cropland in Germany (C stocks of above-ground and below-ground biomass, and total C stocks ± half of the 95 % confidence interval)

Year	Carbon stocks [Mg C ha^{-1}]		
	Bio_{total}	Bio_{above}	Bio_{below}
1990	10.05 ± 1.37	7.00 ± 0.44	3.06 ± 1.21
1991	10.05 ± 1.37	7.00 ± 0.44	3.06 ± 1.21
1992	10.05 ± 1.37	7.00 ± 0.44	3.06 ± 1.21
1993	10.05 ± 1.37	7.00 ± 0.44	3.06 ± 1.21
1994	10.05 ± 1.37	7.00 ± 0.44	3.06 ± 1.21
1995	10.05 ± 1.37	7.00 ± 0.44	3.06 ± 1.21
1996	10.05 ± 1.37	7.00 ± 0.44	3.06 ± 1.21
1997	10.05 ± 1.37	7.00 ± 0.44	3.06 ± 1.21
1998	10.05 ± 1.37	7.00 ± 0.44	3.06 ± 1.21
1999	10.05 ± 1.37	7.00 ± 0.44	3.06 ± 1.21
2000	10.05 ± 1.37	7.00 ± 0.44	3.06 ± 1.21
2001	10.05 ± 1.37	7.00 ± 0.44	3.06 ± 1.21
2002	10.05 ± 1.37	7.00 ± 0.44	3.06 ± 1.21
2003	10.08 ± 1.37	7.02 ± 0.44	3.07 ± 1.22
2004	10.11 ± 1.38	7.04 ± 0.44	3.08 ± 1.22
2005	10.14 ± 1.38	7.06 ± 0.44	3.09 ± 1.23
2006	10.17 ± 1.39	7.08 ± 0.44	3.10 ± 1.23
2007	10.21 ± 1.39	7.10 ± 0.44	3.11 ± 1.23
2008	10.47 ± 1.43	7.30 ± 0.46	3.17 ± 1.26
2009	10.74 ± 1.46	7.50 ± 0.47	3.24 ± 1.29

Year	Carbon stocks [Mg C ha^{-1}]		
	Bio_{total}	Bio_{above}	Bio_{below}
2010	11.01 ± 1.50	7.70 ± 0.48	3.31 ± 1.31
2011	11.27 ± 1.54	7.90 ± 0.49	3.37 ± 1.34
2012	11.54 ± 1.57	8.10 ± 0.51	3.44 ± 1.37
2013	11.54 ± 1.57	8.10 ± 0.51	3.44 ± 1.37

19.4.4 Uncertainties

The uncertainties for the German LULUCF inventory have been determined in accordance with the requirements of the 2006 IPCC Guidelines. The uncertainty statistics commonly given for a normal distribution include the 95 % confidence interval, ± half of the 95 % confidence interval and 1.96 x the standard error, in % of the mean.

In the case of non-symmetric distributions – normally, data with log-normal distributions, as in the present case – the uncertainties are expressed as percentages of the position scale, and as upper and lower bounds. As a rule, they are determined via the quantiles (p = 0.025 and p = 0.975). Pursuant to the 2006 IPCC Guidelines, in such cases propagation of uncertainties is to be calculated via a conservative estimation in which the distance between the extreme value of the sloping axis section and the position scale is defined as half of the 95 % confidence interval.

Table 426 shows the results of the uncertainties calculations for all pools and sub-categories of the German LULUCF inventory, with the exception of harvested wood products. Due to a lack of uncertainties figures for the relevant emission factors, it was not possible to calculate uncertainties for harvested wood products (cf. also Chapter 11.3.1.5). The total uncertainty of the German LULUCF inventory is thus 22.91% with respect to the emissions level and 4.82 % with respect to the emissions trend. The largest contribution to the total uncertainty comes from the biomass pool, followed by the categories organic soils, mineral soils and dead organic matter. All other pools have only marginal contributions, and their impacts on the total uncertainty are virtually imperceptible. With respect to the land-use categories, the largest uncertainties occur in the sub-category forest land remaining forest land. In it, the biomass pool, due to the emission factor's 56 % uncertainty and the absolute size of the pertinent sink (-41,663 Gg CO_2-eq. CO_2 emissions), makes far and away the largest contribution to the total uncertainty of the LULUCF inventory. In this land-use category, mineral soils and dead organic matter rank next in this regard. Their contributions are determined primarily by the size of the relevant emission factors (litter: 294 %; dead wood: 107 %). Outside of the forest sector, emissions from organic soils in the final-use categories of the cropland and grassland i.s.s. categories contribute significantly to the LULUCF inventory's total uncertainty, due to the absolute level of the pertinent emissions (35,050 Gg CO_2-eq.) and to the uncertainty of the relevant emission factors (55 and 60 %, respectively). Other perceptible uncertainties occur, in minor numbers, in all other land-use and transition categories – in most cases, in conjunction with forest land, cropland and grassland (in the strict sense). As a rule, their contributions are < 1%, however.

Table 426: Uncertainty Calculation for the German GHG Emissions from Sector 4.B - 4.F (LULUCF)

	A		B	C		D		E	F	G	H	I	J	K	L	M
	Category	Pool	Gas	Base year emissions [CO_2-eq.]	Base year emissions; contribution in [CO_2-eq.]	Year 2013 emissions [CO_2-eq.]	Year 2013 emissions; contribution in [CO_2-eq.]	Activity data uncertainty (half the 95% confidence interval)	Emission factor uncertainty (half the 95% confidence interval)	Combined uncertainty (half the 95% confidence interval)	Contribution to Variance by Category in Year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
				[Gg a^{-1}]	[Gg a^{-1}]	[Gg a^{-1}]	[Gg a^{-1}]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
4.A.1	Forest Land remaining Forest Land	Mineral soil	CO_2	-15,499.489	15,499.489	-16,059.252	16,059.252	1.234	52.585	52.600	47.921	0.016	0.117	0.865	0.205	0.791
4.A.1	Forest Land remaining Forest Land	Organic soil	CO_2	2,716.827	2,716.827	2,857.863	2,857.863	1.234	24.601	24.632	0.333	0.003	0.021	0.079	0.036	0.007
4.(II).A	Forest Land remaining Forest Land	Organic soil	CH_4	38.325	38.325	40.315	40.315	1.234	1,011.573	1,011.573	0.112	0.000	0.000	0.046	0.001	0.002
4.(II).A	Forest Land remaining Forest Land	Organic soil	N_2O	215.365	215.365	226.545	226.545	1.234	200.686	200.690	0.139	0.000	0.002	0.051	0.003	0.003
4.A.1	Forest Land remaining Forest Land	EF biomass	CO_2	-55,708.642	55,708.642	-41,662.639	41,662.639	1.234	56.354	56.367	370.384	0.058	0.304	3.290	0.531	11.108
4.A.1	Forest Land remaining Forest Land	EF litter	CO_2	485.563	485.563	503.299	503.299	1.234	294.000	294.003	1.470	0.001	0.004	0.152	0.006	0.023
4.A.1	Forest Land remaining Forest Land	EF dead wood	CO_2	-1,430.131	1,430.131	2,091.095	2,091.095	1.234	106.869	106.876	3.354	0.025	0.015	2.626	0.027	6.895
4.(IV).2	Forest Land remaining Forest Land	SOM_N₂O_indirect	N_2O	0.000	0.000	0.000	0.000	1.234	291.535	291.538	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).A.1	Forest Land remaining Forest Land	SOM_N₂O_direct	N_2O	0.000	0.000	0.000	0.000	1.234	206.810	206.814	0.000	0.000	0.000	0.000	0.000	0.000
4.(V).A.1	Forest Land remaining Forest Land	Forest fires / wildfires	CH_4	6.770	6.770	1.092	1.092	15.000	35.000	38.079	0.000	0.000	0.000	0.001	0.000	0.000
4.(V).A.1	Forest Land remaining Forest Land	Forest fires / wildfires	N_2O	4.464	4.464	0.720	0.720	15.000	35.000	38.079	0.000	0.000	0.000	0.001	0.000	0.000
4.(V).A.1	Forest Land remaining Forest Land	Forest fires / wildfires	CO_2	IE		IE		15.000	35.000							0.000
4.(II).A	Forest Land remaining Forest Land	Mineral soil	Drainage	NO		NO										0.000
4.(I).A.1.1	Forest Land remaining Forest Land	Mineral fertiliser	Fertilisati on	NO		NO										0.000
4.A.2.1	Cropland converted to Forest Land	Mineral soil	CO_2	294.409	294.409	-0.071	0.071	9.031	25.002	26.583	0.000	0.002	0.000	0.048	0.000	0.002
4.A.2.1	Cropland converted to Forest Land	Organic soil	CO_2	86.197	86.197	57.482	57.482	9.031	24.601	26.206	0.000	0.000	0.000	0.003	0.005	0.000
4.(II).A	Cropland converted to Forest Land	Organic soil	CH_4	1.216	1.216	0.811	0.811	9.031	1,011.573	1,011.613	0.000	0.000	0.000	0.002	0.000	0.000
4.(II).A	Cropland converted to Forest Land	Organic soil	N_2O	6.833	6.833	4.557	4.557	9.031	200.686	200.889	0.000	0.000	0.000	0.002	0.000	0.000
4.A.2.1	Cropland converted to Forest Land	EF biomass	CO_2	-2,199.472	2,199.472	-1,610.865	1,610.865	9.031	10.217	13.636	0.032	0.003	0.012	0.026	0.150	0.023
4.A.2.1	Cropland converted to Forest Land	EF litter	CO_2	-337.835	337.835	-221.791	221.791	9.031	3.147	9.563	0.000	0.001	0.002	0.002	0.021	0.000
4.A.2.1	Cropland converted to Forest Land	EF dead wood	CO_2	-24.451	24.451	-16.299	16.299	9.031	48.686	49.517	0.000	0.000	0.000	0.002	0.002	0.000
4.(IV).2	Cropland converted to Forest Land	SOM_N₂O_indirect	N_2O	6.885	6.885	0.537	0.537	9.031	292.143	292.282	0.000	0.000	0.000	0.012	0.000	0.000
4.(III).A.2.1	Cropland converted to Forest Land	SOM_N₂O_direct	N_2O	30.599	30.599	2.388	2.388	9.031	207.666	207.862	0.000	0.000	0.000	0.038	0.000	0.001
4.A.2.2.1	Grassland 1 converted to Forest Land	Mineral soil	CO_2	987.111	987.111	470.194	470.194	8.321	42.738	43.541	0.028	0.003	0.003	0.128	0.040	0.018
4.A.2.2.1	Grassland 1 converted to Forest Land	Organic soil	CO_2	218.979	218.979	160.164	160.164	8.321	24.601	25.970	0.001	0.000	0.001	0.006	0.014	0.000
4.(II).A	Grassland 1 converted to Forest Land	Organic soil	CH_4	3.089	3.089	2.259	2.259	8.321	1,011.573	1,011.607	0.000	0.000	0.000	0.004	0.000	0.000
4.(II).A	Grassland 1 converted to Forest Land	Organic soil	N_2O	17.359	17.359	12.696	12.696	8.321	200.686	200.859	0.000	0.000	0.000	0.004	0.001	0.000
4.A.2.2.1	Grassland 1 converted to Forest Land	EF biomass	CO_2	-2,575.762	2,575.762	-1,932.727	1,932.727	8.321	18.932	20.680	0.107	0.003	0.014	0.050	0.166	0.030
4.A.2.2.1	Grassland 1 converted to Forest Land	EF litter	CO_2	-399.370	399.370	-287.567	287.567	8.321	3.147	8.896	0.000	0.000	0.002	0.002	0.025	0.001
4.A.2.2.1	Grassland 1 converted to Forest Land	EF dead wood	CO_2	-28.904	28.904	-21.132	21.132	8.321	48.686	49.392	0.000	0.000	0.000	0.002	0.002	0.000
4.(IV).2	Grassland 1 converted to Forest Land	SOM_N₂O_indirect	N_2O	22.363	22.363	10.652	10.652	8.321	294.192	294.309	0.001	0.000	0.000	0.020	0.001	0.000

A			B	C		D		E	F	G	H	I	J	K	L	M
	Category	Pool	Gas	Base year emissions [CO_2-eq.]	Base year emissions; contribution in [CO_2-eq.]	Year 2013 emissions [CO_2-eq.]	Year 2013 emissions; contribution in [CO_2-eq.]	Activity data uncertainty (half the 95% confidence interval)	Emission factor uncertainty (half the 95% confidence interval)	Combined uncertainty (half the 95% confidence interval)	Contribution to Variance by Category in Year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
				[Gg a^{-1}]	[Gg a^{-1}]	[Gg a^{-1}]	[Gg a^{-1}]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
4.(III).A.2.2.1	Grassland 1 converted to Forest Land	SOM_N_2O_direct	N_2O	99.392	99.392	47.344	47.344	8.321	210.539	210.703	0.007	0.000	0.000	0.063	0.004	0.004
4.A.2.2.2	Woody Grassland converted to Forest Land	Mineral soil	CO_2	103.795	103.795	42.682	42.682	16.089	44.521	47.339	0.000	0.000	0.000	0.016	0.007	0.000
4.A.2.2.2	Woody Grassland converted to Forest Land	Organic soil	CO_2	105.401	105.401	75.099	75.099	16.089	24.601	29.395	0.000	0.000	0.001	0.003	0.012	0.000
4.(II).A	Woody Grassland converted to Forest Land	Organic soil	CH_4	1.487	1.487	1.059	1.059	16.089	1,011.573	1,011.701	0.000	0.000	0.000	0.002	0.000	0.000
4.(II).A	Woody Grassland converted to Forest Land	Organic soil	N_2O	8.355	8.355	5.953	5.953	16.089	200.686	201.330	0.000	0.000	0.000	0.002	0.001	0.000
4.A.2.2.2	Woody Grassland converted to Forest Land	Biomass	CO_2	-167.941	167.941	-224.498	224.498	16.089	51.219	53.687	0.010	0.001	0.002	0.028	0.037	0.002
4.A.2.2.2	Woody Grassland converted to Forest Land	EF litter	CO_2	-64.350	64.350	-45.138	45.138	16.089	3.147	16.394	0.000	0.000	0.000	0.000	0.007	0.000
4.A.2.2.2	Woody Grassland converted to Forest Land	EF dead wood	CO_2	-4.657	4.657	-3.317	3.317	16.089	48.686	51.276	0.000	0.000	0.000	0.000	0.001	0.000
4.(IV).2	Woody Grassland converted to Forest Land	SOM_N_2O_indirect	N_2O	2.440	2.440	1.024	1.024	16.089	294.456	294.895	0.000	0.000	0.000	0.002	0.000	0.000
4.(III).A.2.2.2	Woody Grassland converted to Forest Land	SOM_N_2O_direct	N_2O	10.845	10.845	4.551	4.551	16.089	210.908	211.521	0.000	0.000	0.000	0.008	0.001	0.000
4.A.2.3.3	Other Wetlands converted to Forest Land	Mineral soil	CO_2	48.128	48.128	17.778	17.778	33.059	28.492	43.643	0.000	0.000	0.000	0.005	0.006	0.000
4.A.2.3.3	Other Wetlands converted to Forest Land	Organic soil	CO_2	0.000	0.000	0.000	0.000	33.059	24.601	41.209	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).A	Other Wetlands converted to Forest Land	Organic soil	CH_4	0.000	0.000	0.000	0.000	33.059	1,011.573	1,012.113	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).A	Other Wetlands converted to Forest Land	Organic soil	N_2O	0.000	0.000	0.000	0.000	33.059	200.686	203.391	0.000	0.000	0.000	0.000	0.000	0.000
4.A.2.3.3	Other Wetlands converted to Forest Land	Biomass	CO_2	-104.344	104.344	-92.840	92.840	33.059	36.927	49.563	0.001	0.000	0.001	0.000	0.032	0.001
4.A.2.3.3	Other Wetlands converted to Forest Land	EF litter	CO_2	-20.184	20.184	-11.927	11.927	33.059	3.147	33.209	0.000	0.000	0.000	0.000	0.004	0.000
4.A.2.3.3	Other Wetlands converted to Forest Land	EF dead wood	CO_2	-1.461	1.461	-0.876	0.876	33.059	48.686	58.850	0.000	0.000	0.000	0.000	0.000	0.000
4.(IV).2	Other Wetlands converted to Forest Land	SOM_N_2O_indirect	N_2O	0.896	0.896	0.331	0.331	33.059	292.462	294.325	0.000	0.000	0.000	0.001	0.000	0.000
4.(III).A.2.3.3	Other Wetlands converted to Forest Land	SOM_N_2O_direct	N_2O	3.980	3.980	1.470	1.470	33.059	208.115	210.724	0.000	0.000	0.000	0.003	0.001	0.000
4.A.2.3.2	Flooded Land converted to Forest Land	Mineral soil	CO_2	0.000	0.000	0.000	0.000	49.067	11.248	50.340	0.000	0.000	0.000	0.000	0.000	0.000
4.A.2.3.2	Flooded Land converted to Forest Land	Organic soil	CO_2	0.000	0.000	0.000	0.000	49.067	24.601	54.889	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).A	Flooded Land converted to Forest Land	Organic soil	CH_4	0.000	0.000	0.000	0.000	49.067	1,011.573	1,012.762	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).A	Flooded Land converted to Forest Land	Organic soil	N_2O	0.000	0.000	0.000	0.000	49.067	200.686	206.598	0.000	0.000	0.000	0.000	0.000	0.000
4.A.2.3.2	Flooded Land converted to Forest Land	EF biomass	CO_2	-240.422	240.422	-140.795	140.795	49.067	25.644	55.365	0.004	0.001	0.001	0.014	0.071	0.005
4.A.2.3.2	Flooded Land converted to Forest Land	EF litter	CO_2	-33.610	33.610	-18.088	18.088	49.067	3.147	49.168	0.000	0.000	0.000	0.000	0.009	0.000
4.A.2.3.2	Flooded Land converted to Forest Land	EF dead wood	CO_2	-2.432	2.432	-1.329	1.329	49.067	48.686	69.123	0.000	0.000	0.000	0.000	0.001	0.000
4.(IV).2	Flooded Land converted to Forest Land	SOM_N_2O_indirect	N_2O	0.000	0.000	0.000	0.000	49.067	291.288	295.392	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).A.2.3.2	Flooded Land converted to Forest Land	SOM_N_2O_direct	N_2O	0.000	0.000	0.000	0.000	49.067	206.462	212.213	0.000	0.000	0.000	0.000	0.000	0.000
4.A.2.4	Settlements converted to Forest Land	Mineral soil	CO_2	54.346	54.346	-10.466	10.466	21.020	40.846	45.937	0.000	0.000	0.000	0.018	0.002	0.000
4.A.2.4	Settlements converted to Forest Land	Organic soil	CO_2	73.485	73.485	63.352	63.352	21.020	24.601	32.358	0.000	0.000	0.000	0.000	0.014	0.000
4.A.2.4	Settlements converted to Forest Land	Organic soil	CH_4	1.037	1.037	0.894	0.894	21.020	1,011.573	1,011.791	0.000	0.000	0.000	0.000	0.000	0.000
4.A.2.4	Settlements converted to Forest Land	Organic soil	N_2O	5.825	5.825	5.022	5.022	21.020	200.686	201.784	0.000	0.000	0.000	0.000	0.001	0.000
4.A.2.4	Settlements converted to Forest Land	EF biomass	CO_2	-489.705	489.705	-540.176	540.176	21.020	38.060	43.479	0.037	0.001	0.004	0.029	0.117	0.015
4.A.2.4	Settlements converted to Forest Land	EF litter	CO_2	-83.832	83.832	-71.150	71.150	21.020	3.147	21.254	0.000	0.000	0.001	0.000	0.015	0.000

	A		B	C		D		E	F	G	H	I	J	K	L	M
	Category	Pool	Gas	Base year emissions [CO_2-eq.]	Base year emissions; contribution in [CO_2-eq.]	Year 2013 emissions [CO_2-eq.]	Year 2013 emissions; contribution in [CO_2-eq.]	Activity data uncertainty (half the 95% confidence interval)	Emission factor uncertainty (half the 95% confidence interval)	Combined uncertainty (half the 95% confidence interval)	Contribution to Variance by Category in Year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
				[Gg a^{-1}]	[Gg a^{-1}]	[Gg a^{-1}]	[Gg a^{-1}]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
4.A.2.4	Settlements converted to Forest Land	EF dead wood	CO_2	-6.067	6.067	-5.229	5.229	21.020	48.686	53.030	0.000	0.000	0.000	0.000	0.001	0.000
4.(IV).2	Settlements converted to Forest Land	SOM_N_2O_indirect	N_2O	1.249	1.249	0.041	0.041	21.020	293.923	294.673	0.000	0.000	0.000	0.002	0.000	0.000
4.(III).A.2.4	Settlements converted to Forest Land	SOM_N_2O_direct	N_2O	5.552	5.552	0.184	0.184	21.020	210.163	211.211	0.000	0.000	0.000	0.007	0.000	0.000
4.A.2.5	Other Land converted to Forest Land	Mineral soil	CO_2	16.616	16.616	-8.644	8.644	44.253	43.353	61.950	0.000	0.000	0.000	0.007	0.004	0.000
4.A.2.5	Other Land converted to Forest Land	Organic soil	CO_2	0.000	0.000	0.000	0.000	44.253	24.601	50.631	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).A	Other Land converted to Forest Land	Organic soil	CH_4	0.000	0.000	0.000	0.000	44.253	1,011.573	1,012.540	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).A	Other Land converted to Forest Land	Organic soil	N_2O	0.000	0.000	0.000	0.000	44.253	200.686	205.507	0.000	0.000	0.000	0.000	0.000	0.000
4.A.2.5	Other Land converted to Forest Land	EF biomass	CO_2	-265.201	265.201	-162.079	162.079	44.253	25.644	51.146	0.005	0.001	0.001	0.014	0.074	0.006
4.A.2.5	Other Land converted to Forest Land	EF litter	CO_2	-37.074	37.074	-20.822	20.822	44.253	3.147	44.364	0.000	0.000	0.000	0.000	0.010	0.000
4.A.2.5	Other Land converted to Forest Land	EF dead wood	CO_2	-2.683	2.683	-1.530	1.530	44.253	48.686	65.793	0.000	0.000	0.000	0.000	0.001	0.000
4.(IV).2	Other Land converted to Forest Land	SOM_N_2O_indirect	N_2O	0.376	0.376	0.000	0.000	44.253	294.282	297.590	0.000	0.000	0.000	0.001	0.000	0.000
4.(III).A.2.5	Other Land converted to Forest Land	SOM_N_2O_direct	N_2O	1.670	1.670	0.000	0.000	44.253	210.664	215.262	0.000	0.000	0.000	0.002	0.000	0.000
4.B.1	Cropland remaining Cropland	Mineral soil	CO_2	0.000	0.000	0.000	0.000	1.048	50.505	50.516	0.000	0.000	0.000	0.000	0.000	0.000
4.B.1	Cropland remaining Cropland	Organic soil	CO_2	9,418.781	9,418.781	7,989.893	7,989.893	1.048	45.647	45.659	8.938	0.003	0.058	0.133	0.086	0.025
4.(II).B	Cropland remaining Cropland	Organic soil	CH_4	206.135	206.135	174.863	174.863	1.048	233.927	233.929	0.112	0.000	0.001	0.015	0.002	0.000
4.B.1	Cropland remaining Cropland	EF biomass	CO_2	0.000	0.000	0.000	0.000	1.048	9.251	9.310	0.000	0.000	0.000	0.000	0.000	0.000
4.B.2.1	Forest land converted to cropland	Mineral soil	CO_2	-87.276	87.276	-2.884	2.884	9.031	25.002	26.583	0.000	0.001	0.000	0.014	0.000	0.000
4.B.2.1	Forest land converted to cropland	Organic soil	CO_2	288.134	288.134	164.182	164.182	9.031	45.647	46.531	0.004	0.001	0.001	0.031	0.015	0.001
4.(II).B	Forest land converted to cropland	Organic soil	CH_4	6.306	6.306	3.593	3.593	9.031	233.927	234.101	0.000	0.000	0.000	0.003	0.000	0.000
4.B.2.1	Forest land converted to cropland	EF biomass	CO_2	269.982	269.982	121.056	121.056	9.031	19.900	21.853	0.000	0.001	0.001	0.017	0.011	0.000
4.B.2.1	Forest land converted to cropland	EF DOM	CO_2	247.081	247.081	53.143	53.143	9.031	5.928	10.803	0.000	0.001	0.000	0.007	0.005	0.000
4.(IV).2	Forest land converted to cropland	SOM_N_2O_indirect	N_2O	0.000	0.000	0.061	0.061	9.031	287.841	287.983	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).B.2.1	Forest land converted to cropland	SOM_N_2O_direct	N_2O	0.000	0.000	0.271	0.271	9.031	201.570	201.772	0.000	0.000	0.000	0.000	0.000	0.000
4.B.2.2.1	Grassland 1 converted to Cropland	Mineral soil	CO_2	2,577.413	2,577.413	3,029.301	3,029.301	5.318	49.096	49.384	1.503	0.005	0.022	0.263	0.166	0.097
4.B.2.2.1	Grassland 1 converted to Cropland	Organic soil	CO_2	1,627.625	1,627.625	1,912.990	1,912.990	5.318	45.647	45.955	0.519	0.003	0.014	0.154	0.105	0.035
4.(II).B	Grassland 1 converted to Cropland	Organic soil	CH_4	35.621	35.621	41.867	41.867	5.318	233.927	233.987	0.006	0.000	0.000	0.017	0.002	0.000
4.B.2.2.1	Grassland 1 converted to Cropland	Biomass	CO_2	91.557	91.557	-233.900	233.900	5.318	12.927	13.978	0.001	0.002	0.002	0.030	0.013	0.001
4.(IV).2	Grassland 1 converted to Cropland	SOM_N_2O_indirect	N_2O	58.392	58.392	68.629	68.629	5.318	295.182	295.230	0.028	0.000	0.001	0.036	0.004	0.001
4.(III).B.2.2.1	Grassland 1 converted to Cropland	SOM_N_2O_direct	N_2O	259.519	259.519	305.020	305.020	5.318	211.921	211.988	0.281	0.001	0.002	0.114	0.017	0.013
4.B.2.2.2	Woody Grassland converted to Cropland	Mineral soil	CO_2	70.737	70.737	30.877	30.877	19.954	51.096	54.854	0.000	0.000	0.000	0.012	0.006	0.000
4.B.2.2.2	Woody Grassland converted to Cropland	Organic soil	CO_2	20.017	20.017	8.737	8.737	19.954	45.647	49.817	0.000	0.000	0.000	0.003	0.002	0.000
4.(II).B	Woody Grassland converted to Cropland	Organic soil	CH_4	0.438	0.438	0.191	0.191	19.954	233.927	234.776	0.000	0.000	0.000	0.000	0.000	0.000
4.B.2.2.2	Woody Grassland converted to Cropland	Biomass	CO_2	203.873	203.873	91.622	91.622	19.954	47.051	51.107	0.001	0.001	0.001	0.031	0.019	0.001
4.(IV).2	Woody Grassland converted to Cropland	SOM_N_2O_indirect	N_2O	1.663	1.663	0.726	0.726	19.954	295.522	296.195	0.000	0.000	0.000	0.002	0.000	0.000

A		Pool	B	C		D		E	F	G	H	I	J	K	L	M
	Category	Pool	Gas	Base year emissions [CO_2-eq.] [Gg a⁻¹]	Base year emissions; contribution in [CO_2-eq.] [Gg a⁻¹]	Year 2013 emissions [CO_2-eq.] [Gg a⁻¹]	Year 2013 emissions; contribution in [CO_2-eq.] [Gg a⁻¹]	Activity data uncertainty (half the 95% confidence interval) [%]	Emission factor uncertainty (half the 95% confidence interval) [%]	Combined uncertainty (half the 95% confidence interval) [%]	Contribution to Variance by Category in Year t [%]	Type A sensitivity [%]	Type B sensitivity [%]	Uncertainty in trend in national emissions introduced by emission factor uncertainty [%]	Uncertainty in trend in national emissions introduced by activity data uncertainty [%]	Uncertainty introduced into the trend in total national emissions [%]
4.(III).B.2.2.2	Woody Grassland converted to Cropland	SOM_N_2O_direct	N_2O	7.391	7.391	3.226	3.226	19.954	212.393	213.328	0.000	0.000	0.000	0.005	0.001	0.000
4.B.2.3.3	Other Wetlands converted to Cropland	Mineral soil	CO_2	14.322	14.322	5.524	5.524	102.479	36.759	108.872	0.000	0.000	0.000	0.002	0.006	0.000
4.B.2.3.3	Other Wetlands converted to Cropland	Organic soil	CO_2	0.000	0.000	0.000	0.000	102.479	45.647	112.186	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).B	Other Wetlands converted to Cropland	Organic soil	CH_4	0.000	0.000	0.000	0.000	102.479	233.927	255.390	0.000	0.000	0.000	0.000	0.000	0.000
4.B.2.3.3	Other Wetlands converted to Cropland	Biomass	CO_2	13.059	13.059	0.000	0.000	102.479	31.101	107.095	0.000	0.000	0.000	0.003	0.000	0.000
4.(IV).2	Other Wetlands converted to Cropland	SOM_N_2O_indirect	N_2O	0.267	0.267	0.103	0.103	102.479	295.641	312.899	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).B.2.3.3	Other Wetlands converted to Cropland	SOM_N_2O_direct	N_2O	1.185	1.185	0.457	0.457	102.479	212.559	235.973	0.000	0.000	0.000	0.001	0.000	0.000
4.B.2.3.2	Flooded Land converted to Cropland	Mineral soil	CO_2	0.000	0.000	0.000	0.000	36.886	50.505	62.541	0.000	0.000	0.000	0.000	0.000	0.000
4.B.2.3.2	Flooded Land converted to Cropland	Organic soil	CO_2	0.000	0.000	0.000	0.000	36.886	45.647	58.687	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).B	Flooded Land converted to Cropland	Organic soil	CH_4	0.000	0.000	0.000	0.000	36.886	233.927	236.817	0.000	0.000	0.000	0.000	0.000	0.000
4.B.2.3.2	Flooded Land converted to Cropland	Biomass	CO_2	-14.240	14.240	0.000	0.000	36.886	9.251	38.028	0.000	0.000	0.000	0.001	0.000	0.000
4.(IV).2	Flooded Land converted to Cropland	SOM_N_2O_indirect	N_2O	0.000	0.000	0.000	0.000	36.886	295.420	297.714	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).B.2.3.2	Flooded Land converted to Cropland	SOM_N_2O_direct	N_2O	0.000	0.000	0.000	0.000	36.886	212.252	215.433	0.000	0.000	0.000	0.000	0.000	0.000
4.B.2.4	Settlements converted to Cropland	Mineral soil	CO_2	-11.557	11.557	-8.335	8.335	12.287	49.155	50.667	0.000	0.000	0.000	0.001	0.001	0.000
4.B.2.4	Settlements converted to Cropland	Organic soil	CO_2	669.154	669.154	482.598	482.598	12.287	45.647	47.271	0.035	0.001	0.004	0.038	0.061	0.005
4.(II).B	Settlements converted to Cropland	Organic soil	CH_4	14.645	14.645	10.562	10.562	12.287	233.927	234.249	0.000	0.000	0.000	0.004	0.001	0.000
4.B.2.4	Settlements converted to Cropland	Biomass	CO_2	80.497	80.497	30.807	30.807	12.287	30.109	32.519	0.000	0.000	0.000	0.009	0.004	0.000
4.(IV).2	Settlements converted to Cropland	SOM_N_2O_indirect	N_2O	0.000	0.000	0.000	0.000	12.287	295.192	295.448	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).B.2.4	Settlements converted to Cropland	SOM_N_2O_direct	N_2O	0.000	0.000	0.000	0.000	12.287	211.934	212.290	0.000	0.000	0.000	0.000	0.000	0.000
4.B.2.5	Other Land converted to Cropland	Mineral soil	CO_2	-1.941	1.941	-4.245	4.245	50.648	51.781	72.433	0.000	0.000	0.000	0.001	0.002	0.000
4.B.2.5	Other Land converted to Cropland	Organic soil	CO_2	0.000	0.000	0.000	0.000	50.648	233.927	239.347	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).B	Other Land converted to Cropland	Organic soil	CH_4	0.000	0.000	0.000	0.000	50.648	45.647	68.182	0.000	0.000	0.000	0.000	0.000	0.000
4.B.2.5	Other Land converted to Cropland	Biomass	CO_2	-2.680	2.680	0.000	0.000	50.648	9.251	51.486	0.000	0.000	0.000	0.000	0.000	0.000
4.(IV).2	Other Land converted to Cropland	SOM_N_2O_indirect	N_2O	0.000	0.000	0.000	0.000	50.648	295.641	299.948	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).B.2.5	Other Land converted to Cropland	SOM_N_2O_direct	N_2O	0.000	0.000	0.000	0.000	50.648	212.559	218.510	0.000	0.000	0.000	0.000	0.000	0.000
4.C.1.1	Grassland 1 remaining Grassland 1	Mineral soil	CO_2	0.000	0.000	0.000	0.000	1.626	77.869	77.886	0.000	0.000	0.000	0.000	0.000	0.000
4.C.1.1	Grassland 1 remaining Grassland 1	Organic soil	CO_2	17,881.699	17,881.699	20,392.355	20,392.355	1.626	55.354	55.378	85.648	0.033	0.149	1.801	0.342	3.361
4.(II).C	Grassland 1 remaining Grassland 1	Organic soil	CH_4	378.943	378.943	432.148	432.148	1.626	258.591	258.596	0.839	0.001	0.003	0.179	0.007	0.032
4.C.1.1	Grassland 1 remaining Grassland 1	Biomass	CO_2	0.000	0.000	0.000	0.000	1.626	25.405	25.457	0.000	0.000	0.000	0.000	0.000	0.000
4.C.2.1.1	Forest Land converted to Grassland 1	Mineral soil	CO_2	-149.556	149.556	-93.110	93.110	17.111	42.738	46.036	0.001	0.000	0.001	0.013	0.016	0.000
4.C.2.1.1	Forest Land converted to Grassland 1	Organic soil	CO_2	731.211	731.211	703.857	703.857	17.111	55.354	57.939	0.112	0.000	0.005	0.021	0.124	0.016
4.(II).C	Forest Land converted to Grassland 1	Organic soil	CH_4	15.496	15.496	14.916	14.916	17.111	258.591	259.157	0.001	0.000	0.000	0.002	0.003	0.000
4.C.2.1.1	Forest Land converted to Grassland 1	Biomass	CO_2	246.689	246.689	262.591	262.591	17.111	20.821	26.950	0.003	0.000	0.002	0.007	0.046	0.002
4.C.2.1.1	Forest Land converted to Grassland 1	DOM	CO_2	231.641	231.641	113.296	113.296	17.111	5.928	18.109	0.000	0.001	0.001	0.004	0.020	0.000

	A		B	C		D		E	F	G	H	I	J	K	L	M
	Category	Pool	Gas	Base year emissions [CO_2-eq.]	Base year emissions; contribution in [CO_2-eq.]	Year 2013 emissions [CO_2-eq.]	Year 2013 emissions; contribution in [CO_2-eq.]	Activity data uncertainty (half the 95% confidence interval)	Emission factor uncertainty (half the 95% confidence interval)	Combined uncertainty (half the 95% confidence interval)	Contribution to Variance by Category in Year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
				$[Gg\ a^{-1}]$	$[Gg\ a^{-1}]$	$[Gg\ a^{-1}]$	$[Gg\ a^{-1}]$	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
4.(IV).2	Forest Land converted to Grassland 1	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	17.111	289.921	290.425	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).C.2.1.1	Forest Land converted to Grassland 1	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	17.111	204.528	205.243	0.000	0.000	0.000	0.000	0.000	0.000
4.C.2.2.1	Cropland converted to Grassland 1	Mineral soil	CO_2	-1,634.323	1,634.323	-1,242.563	1,242.563	13.223	49.096	50.846	0.268	0.002	0.009	0.076	0.170	0.035
4.C.2.2.1	Cropland converted to Grassland 1	Organic soil	CO_2	2,881.771	2,881.771	2,200.657	2,200.657	13.223	55.354	56.912	1.053	0.003	0.016	0.148	0.300	0.112
4.(II).C	Cropland converted to Grassland 1	Organic soil	CH_4	61.069	61.069	46.636	46.636	13.223	258.591	258.929	0.010	0.000	0.000	0.015	0.006	0.000
4.C.2.2.1	Cropland converted to Grassland 1	Biomass	CO_2	-66.593	66.593	64.598	64.598	13.223	12.927	18.492	0.000	0.001	0.000	0.012	0.009	0.000
4.(IV).2	Cropland converted to Grassland 1	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	13.223	295.182	295.478	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).C.2.1.1	Cropland converted to Grassland 1	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	13.223	211.921	212.333	0.000	0.000	0.000	0.000	0.000	0.000
4.C.1.3	Woody Grassland converted to Grassland 1	Mineral soil	CO_2	-34.462	34.462	-18.095	18.095	17.196	56.919	59.460	0.000	0.000	0.000	0.005	0.003	0.000
4.C.1.3	Woody Grassland converted to Grassland 1	Organic soil	CO_2	460.350	460.350	242.792	242.792	17.196	55.354	57.964	0.013	0.001	0.002	0.068	0.043	0.006
4.(II).C	Woody Grassland converted to Grassland 1	Organic soil	CH_4	9.756	9.756	5.145	5.145	17.196	258.591	259.162	0.000	0.000	0.000	0.007	0.001	0.000
4.C.1.3	Woody Grassland converted to Grassland 1	Biomass	CO_2	418.835	418.835	66.937	66.937	17.196	47.930	50.922	0.001	0.002	0.000	0.107	0.012	0.012
4.(IV).2	Woody Grassland converted to Grassland 1	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	17.196	296.584	297.082	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).C.1.3	Woody Grassland converted to Grassland 1	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	17.196	213.869	214.559	0.000	0.000	0.000	0.000	0.000	0.000
4.C.2.3.3.1	Other Wetlands converted to Grassland 1	Mineral soil	CO_2	-1.476	1.476	-1.091	1.091	59.180	47.361	75.798	0.000	0.000	0.000	0.000	0.001	0.000
4.C.2.3.3.1	Other Wetlands converted to Grassland 1	Organic soil	CO_2	31.267	31.267	23.209	23.209	59.180	55.354	81.033	0.000	0.000	0.000	0.002	0.014	0.000
4.(II).C	Other Wetlands converted to Grassland 1	Organic soil	CH_4	0.663	0.663	0.492	0.492	59.180	258.591	265.277	0.000	0.000	0.000	0.000	0.000	0.000
4.C.2.3.3.1	Other Wetlands converted to Grassland 1	Biomass	CO_2	8.015	8.015	8.906	8.906	59.180	32.674	67.601	0.000	0.000	0.000	0.000	0.005	0.000
4.(IV).2	Other Wetlands converted to Grassland 1	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	59.180	294.899	300.778	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).C.2.3.3.1	Other Wetlands converted to Grassland 1	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	59.180	211.526	219.648	0.000	0.000	0.000	0.000	0.000	0.000
4.C.2.3.2.1	Flooded Land converted to Grassland 1	Mineral soil	CO_2	0.000	0.000	0.000	0.000	23.079	77.869	81.217	0.000	0.000	0.000	0.000	0.000	0.000
4.C.2.3.2.1	Flooded Land converted to Grassland 1	Organic soil	CO_2	430.656	430.656	273.531	273.531	23.079	55.354	59.973	0.018	0.001	0.002	0.044	0.065	0.006
4.(II).C	Flooded Land converted to Grassland 1	Organic soil	CH_4	9.126	9.126	5.797	5.797	23.079	258.591	259.619	0.000	0.000	0.000	0.004	0.001	0.000
4.C.2.3.2.1	Flooded Land converted to Grassland 1	Biomass	CO_2	-54.166	54.166	-14.678	14.678	23.079	25.405	34.323	0.000	0.000	0.000	0.006	0.003	0.000
4.(IV).2	Flooded Land converted to Grassland 1	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	23.079	301.307	302.189	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).C.2.3.2.1	Flooded Land converted to Grassland 1	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	23.079	220.371	221.577	0.000	0.000	0.000	0.000	0.000	0.000
4.C.2.4.1	Settlements converted to Grassland 1	Mineral soil	CO_2	-288.577	288.577	-259.166	259.166	13.834	57.481	59.123	0.016	0.000	0.002	0.001	0.037	0.001
4.C.2.4.1	Settlements converted to Grassland 1	Organic soil	CO_2	507.293	507.293	457.602	457.602	13.834	55.354	57.057	0.046	0.000	0.003	0.002	0.065	0.004
4.(II).C	Settlements converted to Grassland 1	Organic soil	CH_4	10.750	10.750	9.697	9.697	13.834	258.591	258.961	0.000	0.000	0.000	0.000	0.001	0.000
4.C.2.4.1	Settlements converted to Grassland 1	Biomass	CO_2	110.345	110.345	35.933	35.933	13.834	32.431	35.259	0.000	0.000	0.000	0.015	0.005	0.000
4.(IV).2	Settlements converted to Grassland 1	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	13.834	296.692	297.015	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).C.2.4.1	Settlements converted to Grassland 1	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	13.834	214.019	214.466	0.000	0.000	0.000	0.000	0.000	0.000

	A		B	C		D		E	F	G	H	I	J	K	L	M
	Category	Pool	Gas	Base year emissions [CO_2-eq.]	Base year emissions; contribution in [CO_2-eq.]	Year 2013 emissions [CO_2-eq.]	Year 2013 emissions; contribution in [CO_2-eq.]	Activity data uncertainty (half the 95% confidence interval)	Emission factor uncertainty (half the 95% confidence interval)	Combined uncertainty (half the 95% confidence interval)	Contribution to Variance by Category in Year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
				[Gg a^{-1}]	[Gg a^{-1}]	[Gg a^{-1}]	[Gg a^{-1}]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
4.C.2.5.1	Other Land converted to Grassland 1	Mineral soil	CO_2	-48.705	48.705	-66.838	66.838	35.933	43.353	56.308	0.001	0.000	0.000	0.007	0.025	0.001
4.C.2.5.1	Other Land converted to Grassland 1	Organic soil	CO_2	0.000	0.000	0.000	0.000	35.933	55.354	65.995	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).C	Other Land converted to Grassland 1	Organic soil	CH_4	0.000	0.000	0.000	0.000	35.933	258.591	261.076	0.000	0.000	0.000	0.000	0.000	0.000
4.C.2.5.1	Other Land converted to Grassland 1	Biomass	CO_2	-14.919	14.919	0.000	0.000	35.933	25.405	44.007	0.000	0.000	0.000	0.002	0.000	0.000
4.(IV).2	Other Land converted to Grassland 1	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	35.933	297.124	299.289	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).C.2.5.1	Other Land converted to Grassland 1	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	35.933	214.617	217.604	0.000	0.000	0.000	0.000	0.000	0.000
4.C.1.2	Woody Grassland remaining Woody Grassland	Mineral soil	CO_2	0.000	0.000	0.000	0.000	7.615	83.273	83.621	0.000	0.000	0.000	0.000	0.000	0.000
4.C.1.2	Woody Grassland remaining Woody Grassland	Organic soil	CO_2	162.103	162.103	53.215	53.215	7.615	24.601	25.753	0.000	0.001	0.000	0.016	0.004	0.000
4.(II).C	Woody Grassland remaining Woody Grassland	Organic soil	CH_4	2.287	2.287	0.751	0.751	7.615	1,011.573	1,011.601	0.000	0.000	0.000	0.010	0.000	0.000
4.(II).C	Woody Grassland remaining Woody Grassland	Organic soil	N_2O	12.850	12.850	4.218	4.218	7.615	200.686	200.831	0.000	0.000	0.000	0.011	0.000	0.000
4.C.1.2	Woody Grassland remaining Woody Grassland	Biomass	CO_2	0.000	0.000	0.000	0.000	7.615	55.214	55.737	0.000	0.000	0.000	0.000	0.000	0.000
4.C.2.1.2	Forest Land converted to Woody Grassland	Mineral soil	CO_2	-61.425	61.425	-32.033	32.033	15.457	44.521	47.128	0.000	0.000	0.000	0.007	0.005	0.000
4.C.2.1.2	Forest Land converted to Woody Grassland	Organic soil	CO_2	20.952	20.952	19.951	19.951	15.457	24.601	29.054	0.000	0.000	0.000	0.000	0.003	0.000
4.(II).C	Forest Land converted to Woody Grassland	Organic soil	CH_4	0.296	0.296	0.281	0.281	15.457	1,011.573	1,011.691	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).C	Forest Land converted to Woody Grassland	Organic soil	N_2O	1.661	1.661	1.582	1.582	15.457	200.686	201.280	0.000	0.000	0.000	0.000	0.000	0.000
4.C.2.1.2	Forest Land converted to Woody Grassland	Biomass	CO_2	-45.767	45.767	28.989	28.989	15.457	34.542	37.843	0.000	0.001	0.000	0.018	0.005	0.000
4.C.2.1.2	Forest Land converted to Woody Grassland	EF DOM	CO_2	67.138	67.138	52.197	52.197	15.457	5.928	16.555	0.000	0.000	0.000	0.000	0.008	0.000
4.(IV).2	Forest Land converted to Woody Grassland	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	15.457	290.189	290.600	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).C.2.1.2	Forest Land converted to Woody Grassland	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	15.457	204.908	205.490	0.000	0.000	0.000	0.000	0.000	0.000
4.C.2.2.2	Cropland converted to Woody Grassland	Mineral soil	CO_2	-149.851	149.851	-151.738	151.738	17.630	51.096	54.052	0.005	0.000	0.001	0.007	0.028	0.001
4.C.2.2.2	Cropland converted to Woody Grassland	Organic soil	CO_2	22.218	22.218	22.507	22.507	17.630	24.601	30.266	0.000	0.000	0.000	0.000	0.004	0.000
4.(II).C	Cropland converted to Woody Grassland	Organic soil	CH_4	0.313	0.313	0.317	0.317	17.630	1,011.573	1,011.726	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).C	Cropland converted to Woody Grassland	Organic soil	N_2O	1.761	1.761	1.784	1.784	17.630	200.686	201.459	0.000	0.000	0.000	0.000	0.000	0.000
4.C.2.2.2	Cropland converted to Woody Grassland	Biomass	CO_2	-437.969	437.969	-274.441	274.441	17.630	47.051	50.246	0.013	0.001	0.002	0.040	0.050	0.004
4.(IV).2	Cropland converted to Woody Grassland	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	17.630	295.522	296.047	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).C.2.2.2	Cropland converted to Woody Grassland	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	17.630	212.393	213.124	0.000	0.000	0.000	0.000	0.000	0.000
4.C.1.4	Grassland 1 converted to Woody Grassland	Mineral soil	CO_2	14.636	14.636	43.129	43.129	19.770	56.919	60.255	0.000	0.000	0.000	0.013	0.009	0.000
4.C.1.4	Grassland 1 converted to Woody Grassland	Organic soil	CO_2	22.383	22.383	65.983	65.983	19.770	24.601	31.561	0.000	0.000	0.000	0.008	0.013	0.000
4.(II).C	Grassland 1 converted to Woody Grassland	Organic soil	CH_4	0.316	0.316	0.931	0.931	19.770	1,011.573	1,011.766	0.000	0.000	0.000	0.005	0.000	0.000

A		B	C		D		E	F	G	H	I	J	K	L	M
Category	Pool	Gas	Base year emissions [CO_2-eq.]	Base year emissions; contribution in [CO_2-eq.]	Year 2013 emissions [CO_2-eq.]	Year 2013 emissions; contribution in [CO_2-eq.]	Activity data uncertainty (half the 95% confidence interval)	Emission factor uncertainty (half the 95% confidence interval)	Combined uncertainty (half the 95% confidence interval)	Contribution to Variance by Category in Year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
			[Gg a^{-1}]	[Gg a^{-1}]	[Gg a^{-1}]	[Gg a^{-1}]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
4.(II).C Grassland 1 converted to Woody Grassland	Organic soil	N_2O	1.774	1.774	5.231	5.231	19.770	200.686	201.658	0.000	0.000	0.000	0.005	0.001	0.000
4.C.1.4 Grassland 1 converted to Woody Grassland	Biomass	CO_2	-141.273	141.273	-613.703	613.703	19.770	47.930	51.847	0.068	0.004	0.004	0.171	0.125	0.045
4.(IV).2 Grassland 1 converted to Woody Grassland	SOM_Mineral soil	N_2O	0.332	0.332	0.977	0.977	19.770	296.584	297.242	0.000	0.000	0.000	0.001	0.000	0.000
4.(III).C.1.4 Grassland 1 converted to Woody Grassland	SOM_Mineral soil	N_2O	1.474	1.474	4.343	4.343	19.770	213.869	214.780	0.000	0.000	0.000	0.005	0.001	0.000
4.C.2.3.3.2 Other Wetlands converted to Woody Grassland	Mineral soil	CO_2	0.060	0.060	0.081	0.081	139.405	49.098	147.799	0.000	0.000	0.000	0.000	0.000	0.000
4.C.2.3.3.2 Other Wetlands converted to Woody Grassland	Organic soil	CO_2	0.000	0.000	0.000	0.000	139.405	24.601	141.559	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).C Other Wetlands converted to Woody Grassland	Organic soil	CH_4	0.000	0.000	0.000	0.000	139.405	1,011.573	1,021.133	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).C Other Wetlands converted to Woody Grassland	Organic soil	N_2O	0.000	0.000	0.000	0.000	139.405	200.686	244.354	0.000	0.000	0.000	0.000	0.000	0.000
4.C.2.3.3.2 Other Wetlands converted to Woody Grassland	Biomass	CO_2	-1.781	1.781	0.000	0.000	139.405	34.520	143.616	0.000	0.000	0.000	0.000	0.000	0.000
4.(IV).2 Other Wetlands converted to Woody Grassland	SOM_Mineral soil	N_2O	0.001	0.001	0.002	0.002	139.405	295.183	326.445	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).C.2.3.3.2 Other Wetlands converted to Woody Grassland	SOM_Mineral soil	N_2O	0.005	0.005	0.007	0.007	139.405	211.921	253.662	0.000	0.000	0.000	0.000	0.000	0.000
4.C.2.3.2.2 Flooded Land converted to Woody Grassland	Mineral soil	CO_2	0.000	0.000	0.000	0.000	74.650	83.273	111.835	0.000	0.000	0.000	0.000	0.000	0.000
4.C.2.3.2.2 Flooded Land converted to Woody Grassland	Organic soil	CO_2	8.026	8.026	4.292	4.292	74.650	24.601	78.599	0.000	0.000	0.000	0.001	0.003	0.000
4.(II).C Flooded Land converted to Woody Grassland	Organic soil	CH_4	0.113	0.113	0.061	0.061	74.650	1,011.573	1,014.323	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).C Flooded Land converted to Woody Grassland	Organic soil	N_2O	0.636	0.636	0.340	0.340	74.650	200.686	214.120	0.000	0.000	0.000	0.000	0.000	0.000
4.C.2.3.2.2 Flooded Land converted to Woody Grassland	Biomass	CO_2	-29.884	29.884	-15.808	15.808	74.650	55.214	92.850	0.000	0.000	0.000	0.004	0.012	0.000
4.(IV).2 Flooded Land converted to Woody Grassland	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	74.650	302.748	311.816	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).C.2.3.2.2 Flooded Land converted to Woody Grassland	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	74.650	222.339	234.536	0.000	0.000	0.000	0.000	0.000	0.000
4.C.2.4.2 Settlements converted to Woody Grassland	Mineral soil	CO_2	-64.133	64.133	-69.389	69.389	23.460	59.712	64.156	0.001	0.000	0.001	0.005	0.017	0.000
4.C.2.4.2 Settlements converted to Woody Grassland	Organic soil	CO_2	28.881	28.881	31.261	31.261	23.460	24.601	33.994	0.000	0.000	0.000	0.001	0.008	0.000
4.(II).C Settlements converted to Woody Grassland	Organic soil	CH_4	0.407	0.407	0.441	0.441	23.460	1,011.573	1,011.845	0.000	0.000	0.000	0.001	0.000	0.000

A			B	C		D		E	F	G	H	I	J	K	L	M
	Category	Pool	Gas	Base year emissions [CO_2-eq.] [Gg a^{-1}]	Base year emissions; contribution in [CO_2-eq.] [Gg a^{-1}]	Year 2013 emissions [CO_2-eq.] [Gg a^{-1}]	Year 2013 emissions; contribution in [CO_2-eq.] [Gg a^{-1}]	Activity data uncertainty (half the 95% confidence interval) [%]	Emission factor uncertainty (half the 95% confidence interval) [%]	Combined uncertainty (half the 95% confidence interval) [%]	Contribution to Variance by Category in Year t [%]	Type A sensitivity [%]	Type B sensitivity [%]	Uncertainty in trend in national emissions introduced by emission factor uncertainty [%]	Uncertainty in trend in national emissions introduced by activity data uncertainty [%]	Uncertainty introduced into the trend in total national emissions [%]
4.(II).C	Settlements converted to Woody Grassland	Organic soil	N_2O	2.289	2.289	2.478	2.478	23.460	200.686	202.053	0.000	0.000	0.000	0.001	0.001	0.000
4.C.2.4.2	Settlements converted to Woody Grassland	Biomass	CO_2	-152.719	152.719	-66.607	66.607	23.460	44.169	50.013	0.001	0.001	0.000	0.022	0.016	0.001
4.(IV).2	Settlements converted to Woody Grassland	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	23.460	297.133	298.057	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).C.2.4.2	Settlements converted to Woody Grassland	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	23.460	214.629	215.907	0.000	0.000	0.000	0.000	0.000	0.000
4.C.2.5.2	Other Land converted to Woody Grassland	Mineral soil	CO_2	-7.677	7.677	-11.034	11.034	82.097	62.020	102.890	0.000	0.000	0.000	0.002	0.009	0.000
4.C.2.5.2	Other Land converted to Woody Grassland	Organic soil	CO_2	0.000	0.000	0.000	0.000	82.097	24.601	85.703	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).C	Other Land converted to Woody Grassland	Organic soil	CH_4	0.000	0.000	0.000	0.000	82.097	1,011.573	1,014.899	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).C	Other Land converted to Woody Grassland	Organic soil	N_2O	0.000	0.000	0.000	0.000	82.097	200.686	216.829	0.000	0.000	0.000	0.000	0.000	0.000
4.C.2.5.2	Other Land converted to Woody Grassland	Biomass	CO_2	-18.852	18.852	0.000	0.000	82.097	55.214	98.937	0.000	0.000	0.000	0.007	0.000	0.000
4.(IV).2	Other Land converted to Woody Grassland	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	82.097	297.605	308.721	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).C.2.5.2	Other Land converted to Woody Grassland	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	82.097	215.282	230.405	0.000	0.000	0.000	0.000	0.000	0.000
4.D.1.3	Other Wetlands remaining Other Wetlands	Mineral soil	CO_2	0.000	0.000	0.000	0.000	24.789	52.479	58.040	0.000	0.000	0.000	0.000	0.000	0.000
4.D.1.3	Other Wetlands remaining Other Wetlands	Organic soil	CO_2	277.804	277.804	300.086	300.086	24.789	59.936	64.860	0.025	0.000	0.002	0.023	0.077	0.006
4.(II).D.3	Other Wetlands remaining Other Wetlands	Organic soil	CH_4	5.828	5.828	6.296	6.296	24.789	669.852	670.310	0.001	0.000	0.000	0.005	0.002	0.000
4.(II).D.3	Other Wetlands remaining Other Wetlands	Organic soil	N_2O	2.183	2.183	2.358	2.358	24.789	306.177	307.179	0.000	0.000	0.000	0.001	0.001	0.000
4.D.1.3	Other Wetlands remaining Other Wetlands	Biomass	CO_2	0.000	0.000	0.000	0.000	24.789	43.339	49.928	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.1.3	Forest Land converted to Other Wetlands	Mineral soil	CO_2	-5.806	5.806	-8.940	8.940	62.610	28.492	68.788	0.000	0.000	0.000	0.001	0.006	0.000
4.D.2.1.3	Forest Land converted to Other Wetlands	Organic soil	CO_2	0.000	0.000	0.000	0.000	62.610	59.936	86.674	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.3	Forest Land converted to Other Wetlands	Organic soil	CH_4	0.000	0.000	0.000	0.000	62.610	669.852	672.771	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.3	Forest Land converted to Other Wetlands	Organic soil	N_2O	0.000	0.000	0.000	0.000	62.610	306.177	312.513	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.1.3	Forest Land converted to Other Wetlands	Biomass	CO_2	2.584	2.584	0.000	0.000	62.610	22.816	66.638	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.1.3	Forest Land converted to Other Wetlands	EF DOM	CO_2	5.353	5.353	0.000	0.000	62.610	5.928	62.890	0.000	0.000	0.000	0.000	0.000	0.000
4.(IV).2	Forest Land converted to Other Wetlands	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	62.610	288.165	294.889	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).D.2.1.3	Forest Land converted to Other Wetlands	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	62.610	202.032	211.511	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.2.3	Cropland converted to Other Wetlands	Mineral soil	CO_2	-3.370	3.370	-1.367	1.367	81.251	36.759	89.180	0.000	0.000	0.000	0.000	0.001	0.000
4.D.2.2.3	Cropland converted to Other Wetlands	Organic soil	CO_2	3.911	3.911	1.700	1.700	81.251	59.936	100.966	0.000	0.000	0.000	0.001	0.001	0.000
4.(II).D.3	Cropland converted to Other Wetlands	Organic soil	CH_4	0.082	0.082	0.036	0.036	81.251	669.852	674.762	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.3	Cropland converted to Other Wetlands	Organic soil	N_2O	0.031	0.031	0.013	0.013	81.251	306.177	316.775	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.2.3	Cropland converted to Other Wetlands	Biomass	CO_2	-4.199	4.199	-4.151	4.151	81.251	31.101	87.000	0.000	0.000	0.000	0.000	0.003	0.000
4.(IV).2	Cropland converted to Other Wetlands	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	81.251	293.383	304.426	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).D.2.2.3	Cropland converted to Other Wetlands	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	81.251	209.407	224.617	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.3.1.3	Grassland 1 converted to Other Wetlands	Mineral soil	CO_2	2.699	2.699	7.997	7.997	36.755	47.361	59.950	0.000	0.000	0.000	0.002	0.003	0.000
4.D.2.3.1.3	Grassland 1 converted to Other Wetlands	Organic soil	CO_2	5.760	5.760	18.299	18.299	36.755	59.936	70.308	0.000	0.000	0.000	0.006	0.007	0.000
4.(II).D.3	Grassland 1 converted to Other Wetlands	Organic soil	CH_4	0.121	0.121	0.384	0.384	36.755	669.852	670.859	0.000	0.000	0.000	0.001	0.000	0.000

	A		B	C		D		E	F	G	H	I	J	K	L	M
	Category	Pool	Gas	Base year emissions [CO_2-eq.] [Gg a^{-1}]	Base year emissions; contribution in [CO_2-eq.] [Gg a^{-1}]	Year 2013 emissions [CO_2-eq.] [Gg a^{-1}]	Year 2013 emissions; contribution in [CO_2-eq.] [Gg a^{-1}]	Activity data uncertainty (half the 95% confidence interval) [%]	Emission factor uncertainty (half the 95% confidence interval) [%]	Combined uncertainty (half the 95% confidence interval) [%]	Contribution to Variance by Category in Year t [%]	Type A sensitivity [%]	Type B sensitivity [%]	Uncertainty in trend in national emissions introduced by emission factor uncertainty [%]	Uncertainty in trend in national emissions introduced by activity data uncertainty [%]	Uncertainty introduced into the trend in total national emissions [%]
4.(II).D.3	Grassland 1 converted to Other Wetlands	Organic soil	N_2O	0.045	0.045	0.144	0.144	36.755	306.177	308.375	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.3.1.3	Grassland 1 converted to Other Wetlands	Biomass	CO_2	-11.144	11.144	-60.775	60.775	36.755	32.674	49.178	0.001	0.000	0.000	0.012	0.023	0.001
4.(IV).2	Grassland 1 converted to Other Wetlands	SOM_Mineral soil	N_2O	0.061	0.061	0.181	0.181	36.755	294.899	297.180	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).D.2.3.1.3	Grassland 1 converted to Other Wetlands	SOM_Mineral soil	N_2O	0.272	0.272	0.805	0.805	36.755	211.526	214.695	0.000	0.000	0.000	0.001	0.000	0.000
4.D.2.3.2.3	Woody Grassland converted to Other Wetlands	Mineral soil	CO_2	-0.330	0.330	-0.115	0.115	109.350	49.098	119.867	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.3.2.3	Woody Grassland converted to Other Wetlands	Organic soil	CO_2	0.000	0.000	0.000	0.000	109.350	59.936	124.699	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.3	Woody Grassland converted to Other Wetlands	Organic soil	CH_4	0.000	0.000	0.000	0.000	109.350	669.852	678.719	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.3	Woody Grassland converted to Other Wetlands	Organic soil	N_2O	0.000	0.000	0.000	0.000	109.350	306.177	325.118	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.3.2.3	Woody Grassland converted to Other Wetlands	Biomass	CO_2	9.807	9.807	0.000	0.000	109.350	34.520	114.670	0.000	0.000	0.000	0.002	0.000	0.000
4.(IV).2	Woody Grassland converted to Other Wetlands	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	109.350	295.183	314.786	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).D.2.3.2.3	Woody Grassland converted to Other Wetlands	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	109.350	211.921	238.470	0.000	0.000	0.000	0.000	0.000	0.000
4.D.1.6	Flooded Land converted to Other Wetlands	Mineral soil	CO_2	0.000	0.000	0.000	0.000	92.915	52.479	106.711	0.000	0.000	0.000	0.000	0.000	0.000
4.D.1.6	Flooded Land converted to Other Wetlands	Organic soil	CO_2	0.000	0.000	0.000	0.000	92.915	59.936	110.569	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.3	Flooded Land converted to Other Wetlands	Organic soil	CH_4	0.000	0.000	0.000	0.000	92.915	669.852	676.265	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.3	Flooded Land converted to Other Wetlands	Organic soil	N_2O	0.000	0.000	0.000	0.000	92.915	306.177	319.965	0.000	0.000	0.000	0.000	0.000	0.000
4.D.1.6	Flooded Land converted to Other Wetlands	Biomass	CO_2	-2.748	2.748	0.000	0.000	92.915	43.339	102.525	0.000	0.000	0.000	0.001	0.000	0.000
4.(IV).2	Flooded Land converted to Other Wetlands	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	92.915	295.764	310.015	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).D.1.6	Flooded Land converted to Other Wetlands	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	92.915	212.730	232.136	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.4.3	Settlements converted to Other Wetlands	Mineral soil	CO_2	-6.733	6.733	-2.357	2.357	89.168	47.631	101.092	0.000	0.000	0.000	0.001	0.002	0.000
4.D.2.4.3	Settlements converted to Other Wetlands	Organic soil	CO_2	0.000	0.000	0.000	0.000	89.168	59.936	107.440	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.3	Settlements converted to Other Wetlands	Organic soil	CH_4	0.000	0.000	0.000	0.000	89.168	669.852	675.761	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.3	Settlements converted to Other Wetlands	Organic soil	N_2O	0.000	0.000	0.000	0.000	89.168	306.177	318.897	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.4.3	Settlements converted to Other Wetlands	Biomass	CO_2	-2.804	2.804	0.000	0.000	89.168	32.320	94.845	0.000	0.000	0.000	0.001	0.000	0.000
4.(IV).2	Settlements converted to Other Wetlands	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	89.168	294.942	308.126	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).D.2.4.3	Settlements converted to Other Wetlands	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	89.168	211.586	229.608	0.000	0.000	0.000	0.000	0.000	0.000

	A		B	C		D		E	F	G	H	I	J	K	L	M
	Category	Pool	Gas	Base year emissions [CO_2-eq.]	Base year emissions; contribution in [CO_2-eq.]	Year 2013 emissions [CO_2-eq.]	Year 2013 emissions; contribution in [CO_2-eq.]	Activity data uncertainty (half the 95% confidence interval)	Emission factor uncertainty (half the 95% confidence interval)	Combined uncertainty (half the 95% confidence interval)	Contribution to Variance by Category in Year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
				[Gg a^{-1}]	[Gg a^{-1}]	[Gg a^{-1}]	[Gg a^{-1}]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
4.D.2.5.3	Other Land converted to Other Wetlands	Mineral soil	CO_2	0.000	0.000	0.000	0.000	70.791	49.850	86.581	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.5.3	Other Land converted to Other Wetlands	Organic soil	CO_2	0.000	0.000	0.000	0.000	70.791	59.936	92.756	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.3	Other Land converted to Other Wetlands	Organic soil	CH_4	0.000	0.000	0.000	0.000	70.791	669.852	673.582	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.3	Other Land converted to Other Wetlands	Organic soil	N_2O	0.000	0.000	0.000	0.000	70.791	306.177	314.254	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.5.3	Other Land converted to Other Wetlands	Biomass	CO_2	0.000	0.000	0.000	0.000	70.791	43.339	83.003	0.000	0.000	0.000	0.000	0.000	0.000
4.(IV).2	Other Land converted to Other Wetlands	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	70.791	295.309	303.675	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).D.2.5.3	Other Land converted to Other Wetlands	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	70.791	212.097	223.598	0.000	0.000	0.000	0.000	0.000	0.000
4.D.1.2	Flooded Land remaining Flooded Land	Mineral soil	CO_2	0.000	0.000	0.000	0.000	5.703	0.000	5.703	0.000	0.000	0.000	0.000	0.000	0.000
4.D.1.2	Flooded Land remaining Flooded Land	Organic soil	CO_2	0.000	0.000	0.000	0.000	5.703	0.000	5.703	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.2	Flooded Land remaining Flooded Land	Organic soil	CH_4	0.000	0.000	0.000	0.000	5.703	0.000	5.703	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.2	Flooded Land remaining Flooded Land	Organic soil	N_2O	0.000	0.000	0.000	0.000	5.703	0.000	5.703	0.000	0.000	0.000	0.000	0.000	0.000
4.D.1.2	Flooded Land remaining Flooded Land	Biomass	CO_2	0.000	0.000	0.000	0.000	5.703	0.000	5.703	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.1.2	Forest Land converted to Flooded Land	Mineral soil	CO_2	0.000	0.000	0.000	0.000	52.546	11.248	53.736	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.1.2	Forest Land converted to Flooded Land	Organic soil	CO_2	0.000	0.000	0.000	0.000	52.546	0.000	52.546	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D	Forest Land converted to Flooded Land	Organic soil	CH_4	0.000	0.000	0.000	0.000	52.546	0.000	52.546	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D	Forest Land converted to Flooded Land	Organic soil	N_2O	0.000	0.000	0.000	0.000	52.546	0.000	52.546	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.1.2	Forest Land converted to Flooded Land	Biomass	CO_2	53.851	53.851	0.000	0.000	52.546	24.952	58.169	0.000	0.000	0.000	0.009	0.000	0.000
4.D.2.1.2	Forest Land converted to Flooded Land	EF DOM	CO_2	38.879	38.879	0.000	0.000	52.546	5.928	52.879	0.000	0.000	0.000	0.001	0.000	0.000
4.(IV).2	Forest Land converted to Flooded Land	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	52.546	286.974	291.745	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).D.2.1.2	Forest Land converted to Flooded Land	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	52.546	200.329	207.106	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.2.2	Cropland converted to Flooded Land	Mineral soil	CO_2	0.000	0.000	0.000	0.000	26.064	50.505	56.834	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.2.2	Cropland converted to Flooded Land	Organic soil	CO_2	0.000	0.000	0.000	0.000	26.064	0.000	26.064	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.2	Cropland converted to Flooded Land	Organic soil	CH_4	0.000	0.000	0.000	0.000	26.064	0.000	26.064	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.2	Cropland converted to Flooded Land	Organic soil	N_2O	0.000	0.000	0.000	0.000	26.064	0.000	26.064	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.2.2	Cropland converted to Flooded Land	Biomass	CO_2	29.687	29.687	8.250	8.250	26.064	9.251	27.657	0.000	0.000	0.000	0.001	0.002	0.000
4.(IV).2	Cropland converted to Flooded Land	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	26.064	295.420	296.568	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).D.2.2.2	Cropland converted to Flooded Land	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	26.064	212.252	213.846	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.3.1.2	Grassland 1 converted to Flooded Land	Mineral soil	CO_2	0.000	0.000	0.000	0.000	30.447	77.869	83.610	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.3.1.2	Grassland 1 converted to Flooded Land	Organic soil	CO_2	0.000	0.000	0.000	0.000	30.447	0.000	30.447	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.2	Grassland 1 converted to Flooded Land	Organic soil	CH_4	0.000	0.000	0.000	0.000	30.447	0.000	30.447	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.2	Grassland 1 converted to Flooded Land	Organic soil	N_2O	0.000	0.000	0.000	0.000	30.447	0.000	30.447	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.3.1.2	Grassland 1 converted to Flooded Land	Biomass	CO_2	26.587	26.587	12.225	12.225	30.447	25.405	39.654	0.000	0.000	0.000	0.002	0.004	0.000
4.(IV).2	Grassland 1 converted to Flooded Land	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	30.447	301.307	302.841	0.000	0.000	0.000	0.000	0.000	0.000

A			B	C		D		E	F	G	H	I	J	K	L	M
	Category	Pool	Gas	Base year emissions [CO_2-eq.]	Base year emissions; contribution in [CO_2-eq.]	Year 2013 emissions [CO_2-eq.]	Year 2013 emissions; contribution in [CO_2-eq.]	Activity data uncertainty (half the 95% confidence interval)	Emission factor uncertainty (half the 95% confidence interval)	Combined uncertainty (half the 95% confidence interval)	Contribution to Variance by Category in Year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
				[Gg a^{-1}]	[Gg a^{-1}]	[Gg a^{-1}]	[Gg a^{-1}]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
4.(III).D.2.3.1.2	Grassland 1 converted to Flooded Land	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	30.447	220.371	222.465	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.2.2.2	Woody Grassland converted to Flooded Land	Mineral soil	CO_2	0.000	0.000	0.000	0.000	82.352	83.273	117.117	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.2.2.2	Woody Grassland converted to Flooded Land	Organic soil	CO_2	0.000	0.000	0.000	0.000	82.352	0.000	82.352	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.2	Woody Grassland converted to Flooded Land	Organic soil	CH_4	0.000	0.000	0.000	0.000	82.352	0.000	82.352	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.2	Woody Grassland converted to Flooded Land	Organic soil	N_2O	0.000	0.000	0.000	0.000	82.352	0.000	82.352	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.2.2.2	Woody Grassland converted to Flooded Land	Biomass	CO_2	28.448	28.448	0.000	0.000	82.352	55.214	99.149	0.000	0.000	0.000	0.010	0.000	0.000
4.(IV).2	Woody Grassland converted to Flooded Land	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	82.352	302.748	313.749	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).D.2.2.2.2	Woody Grassland converted to Flooded Land	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	82.352	222.339	237.100	0.000	0.000	0.000	0.000	0.000	0.000
4.D.1.5	Other Wetlands converted to Flooded Land	Mineral soil	CO_2	0.000	0.000	0.000	0.000	196.591	52.479	203.475	0.000	0.000	0.000	0.000	0.000	0.000
4.D.1.5	Other Wetlands converted to Flooded Land	Organic soil	CO_2	0.000	0.000	0.000	0.000	196.591	0.000	196.591	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.2	Other Wetlands converted to Flooded Land	Organic soil	CH_4	0.000	0.000	0.000	0.000	196.591	0.000	196.591	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.2	Other Wetlands converted to Flooded Land	Organic soil	N_2O	0.000	0.000	0.000	0.000	196.591	0.000	196.591	0.000	0.000	0.000	0.000	0.000	0.000
4.D.1.5	Other Wetlands converted to Flooded Land	Biomass	CO_2	0.000	0.000	0.000	0.000	196.591	43.339	201.311	0.000	0.000	0.000	0.000	0.000	0.000
4.(IV).2	Other Wetlands converted to Flooded Land	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	196.591	295.764	355.140	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).D.1.5	Other Wetlands converted to Flooded Land	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	196.591	212.730	289.659	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.4.2	Settlements converted to Flooded Land	Mineral soil	CO_2	0.000	0.000	0.000	0.000	41.354	84.966	94.495	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.4.2	Settlements converted to Flooded Land	Organic soil	CO_2	0.000	0.000	0.000	0.000	41.354	0.000	41.354	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.2	Settlements converted to Flooded Land	Organic soil	CH_4	0.000	0.000	0.000	0.000	41.354	0.000	41.354	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.2	Settlements converted to Flooded Land	Organic soil	N_2O	0.000	0.000	0.000	0.000	41.354	0.000	41.354	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.4.2	Settlements converted to Flooded Land	Biomass	CO_2	31.482	31.482	22.859	22.859	41.354	47.930	63.304	0.000	0.000	0.000	0.002	0.010	0.000
4.(IV).2	Settlements converted to Flooded Land	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	41.354	303.218	306.025	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).D.2.4.2	Settlements converted to Flooded Land	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	41.354	222.978	226.780	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.5.2	Other Land converted to Flooded Land	Mineral soil	CO_2	0.000	0.000	0.000	0.000	100.273	92.858	136.664	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.5.2	Other Land converted to Flooded Land	Organic soil	CO_2	0.000	0.000	0.000	0.000	100.273	0.000	100.273	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).D.2	Other Land converted to Flooded Land	Organic soil	CH_4	0.000	0.000	0.000	0.000	100.273	0.000	100.273	0.000	0.000	0.000	0.000	0.000	0.000

A			B	C		D		E	F	G	H	I	J	K	L	M
	Category	Pool	Gas	Base year emissions [CO_2-eq.] [Gg a-1]	Base year emissions; contribution in [CO_2-eq.] [Gg a-1]	Year 2013 emissions [CO_2-eq.] [Gg a-1]	Year 2013 emissions; contribution in [CO_2-eq.] [Gg a-1]	Activity data uncertainty (half the 95% confidence interval) [%]	Emission factor uncertainty (half the 95% confidence interval) [%]	Combined uncertainty (half the 95% confidence interval) [%]	Contribution to Variance by Category in Year t [%]	Type A sensitivity [%]	Type B sensitivity [%]	Uncertainty in trend in national emissions introduced by emission factor uncertainty [%]	Uncertainty in trend in national emissions introduced by activity data uncertainty [%]	Uncertainty introduced into the trend in total national emissions [%]
4.(II).D.2	Other Land converted to Flooded Land	Organic soil	N_2O	0.000	0.000	0.000	0.000	100.273	0.000	100.273	0.000	0.000	0.000	0.000	0.000	0.000
4.D.2.5.2	Other Land converted to Flooded Land	Biomass	CO_2	0.000	0.000	0.000	0.000	100.273	0.000	100.273	0.000	0.000	0.000	0.000	0.000	0.000
4.(IV).2	Other Land converted to Flooded Land	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	100.273	305.524	321.558	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).D.2.5.2	Other Land converted to Flooded Land	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	100.273	226.103	247.340	0.000	0.000	0.000	0.000	0.000	0.000
4.D.1.1	Peat Extraction remaining Peat Extraction	Organic soil	CO_2	2,146.750	2,146.750	2,159.262	2,159.262	24.789	37.390	44.861	0.630	0.002	0.016	0.067	0.553	0.310
4.(II).D.1	Peat Extraction remaining Peat Extraction	Organic soil	CH_4	5.556	5.556	5.556	5.556	24.789	92.864	96.116	0.000	0.000	0.000	0.000	0.001	0.000
4.(II).D.1	Peat Extraction remaining Peat Extraction	Organic soil	N_2O	7.923	7.923	7.923	7.923	24.789	63.272	67.955	0.000	0.000	0.000	0.000	0.002	0.000
4.D.1.1	Peat Extraction remaining Peat Extraction	Biomass	CO_2	0.000	0.000	0.000	0.000	24.789	0.000	24.789	0.000	0.000	0.000	0.000	0.000	0.000
4.E.1	Settlements remaining Settlements	Mineral soil	CO_2	0.000	0.000	0.000	0.000	2.480	84.966	85.002	0.000	0.000	0.000	0.000	0.000	0.000
4.E.1	Settlements remaining Settlements	Organic soil	CO_2	820.598	820.598	474.077	474.077	2.480	55.354	55.410	0.046	0.002	0.003	0.104	0.012	0.011
4.(II).H.1	Settlements remaining Settlements	Organic soil	CH_4	17.390	17.390	10.046	10.046	2.480	258.591	258.603	0.000	0.000	0.000	0.010	0.000	0.000
4.(II).H.1	Settlements remaining Settlements	Organic soil	N_2O	38.239	38.239	22.091	22.091	2.480	222.682	222.696	0.002	0.000	0.000	0.019	0.001	0.000
4.E.1	Settlements remaining Settlements	Biomass	CO_2	0.000	0.000	0.000	0.000	2.480	47.930	47.994	0.000	0.000	0.000	0.000	0.000	0.000
4.E.2.1	Forest land converted to settlements	Mineral soil	CO_2	-126.313	126.313	34.291	34.291	16.630	40.846	44.101	0.000	0.001	0.000	0.044	0.006	0.002
4.E.2.1	Forest land converted to settlements	Organic soil	CO_2	41.267	41.267	42.166	42.166	16.630	55.354	57.798	0.000	0.000	0.000	0.002	0.007	0.000
4.(II).H.1	Forest land converted to settlements	Organic soil	CH_4	0.875	0.875	0.894	0.894	16.630	258.591	259.125	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).H.1	Forest land converted to settlements	Organic soil	N_2O	1.923	1.923	1.965	1.965	16.630	222.682	223.303	0.000	0.000	0.000	0.000	0.000	0.000
4.E.2.1	Forest land converted to settlements	Biomass	CO_2	288.386	288.386	1,181.372	1,181.372	16.630	22.636	28.088	0.074	0.007	0.009	0.153	0.203	0.064
4.E.2.1	Forest land converted to settlements	EF DOM	CO_2	365.799	365.799	579.486	579.486	16.630	5.928	17.655	0.007	0.002	0.004	0.011	0.099	0.010
4.(IV).2	Forest land converted to settlements	SOM_Mineral soil	N_2O	0.000	0.000	0.505	0.505	16.630	289.648	290.125	0.000	0.000	0.000	0.001	0.000	0.000
4.(III).E.2.1	Forest land converted to settlements	SOM_Mineral soil	N_2O	0.000	0.000	2.245	2.245	16.630	204.141	204.817	0.000	0.000	0.000	0.003	0.000	0.000
4.E.2.2	Cropland converted to Settlements	Mineral soil	CO_2	85.607	85.607	127.177	127.177	9.017	49.155	49.975	0.003	0.000	0.001	0.018	0.012	0.000
4.E.2.2	Cropland converted to Settlements	Organic soil	CO_2	532.662	532.662	791.314	791.314	9.017	55.354	56.084	0.132	0.002	0.006	0.128	0.074	0.022
4.(II).H.1	Cropland converted to Settlements	Organic soil	CH_4	11.288	11.288	16.769	16.769	9.017	258.591	258.748	0.001	0.000	0.000	0.013	0.002	0.000
4.(II).H.1	Cropland converted to Settlements	Organic soil	N_2O	24.821	24.821	36.874	36.874	9.017	222.682	222.865	0.005	0.000	0.000	0.024	0.003	0.001
4.E.2.2	Cropland converted to Settlements	Biomass	CO_2	-424.704	424.704	-782.379	782.379	9.017	30.109	31.430	0.041	0.003	0.006	0.089	0.073	0.013
4.(IV).2	Cropland converted to Settlements	SOM_Mineral soil	N_2O	2.002	2.002	2.974	2.974	9.017	295.192	295.330	0.000	0.000	0.000	0.003	0.000	0.000
4.(III).E.2.2	Cropland converted to Settlements	SOM_Mineral soil	N_2O	8.897	8.897	13.218	13.218	9.017	211.934	212.126	0.001	0.000	0.000	0.008	0.001	0.000
4.E.2.3.1	Grassland 1 converted to Settlements	Mineral soil	CO_2	550.418	550.418	766.020	766.020	14.163	57.481	59.200	0.138	0.002	0.006	0.116	0.112	0.026
4.E.2.3.1	Grassland 1 converted to Settlements	Organic soil	CO_2	344.946	344.946	480.064	480.064	14.163	55.354	57.137	0.051	0.001	0.004	0.070	0.070	0.010
4.(II).H.1	Grassland 1 converted to Settlements	Organic soil	CH_4	7.310	7.310	10.173	10.173	14.163	258.591	258.979	0.000	0.000	0.000	0.007	0.001	0.000
4.(II).H.1	Grassland 1 converted to Settlements	Organic soil	N_2O	16.074	16.074	22.370	22.370	14.163	222.682	223.132	0.002	0.000	0.000	0.013	0.003	0.000
4.E.2.3.1	Grassland 1 converted to Settlements	Biomass	CO_2	-182.974	182.974	-339.485	339.485	14.163	32.431	35.389	0.010	0.001	0.002	0.042	0.050	0.004

A			B	C		D		E	F	G	H	I	J	K	L	M
	Category	Pool	Gas	Base year emissions [CO_2-eq.]	Base year emissions; contribution in [CO_2-eq.]	Year 2013 emissions [CO_2-eq.]	Year 2013 emissions; contribution in [CO_2-eq.]	Activity data uncertainty (half the 95% confidence interval)	Emission factor uncertainty (half the 95% confidence interval)	Combined uncertainty (half the 95% confidence interval)	Contribution to Variance by Category in Year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
				[Gg a^{-1}]	[Gg a^{-1}]	[Gg a^{-1}]	[Gg a^{-1}]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
4.(IV).2	Grassland 1 converted to Settlements	SOM_Mineral soil	N_2O	12.470	12.470	17.354	17.354	14.163	296.692	297.030	0.002	0.000	0.000	0.014	0.003	0.000
4.(III).E.2.3.1	Grassland 1 converted to Settlements	SOM_Mineral soil	N_2O	55.421	55.421	77.130	77.130	14.163	214.019	214.487	0.018	0.000	0.001	0.043	0.011	0.002
4.E.2.3.2	Woody Grassland converted to Settlements	Mineral soil	CO_2	63.449	63.449	35.956	35.956	41.120	59.712	72.501	0.000	0.000	0.000	0.009	0.015	0.000
4.E.2.3.2	Woody Grassland converted to Settlements	Organic soil	CO_2	52.461	52.461	29.729	29.729	41.120	55.354	68.956	0.000	0.000	0.000	0.007	0.013	0.000
4.(II).H.1	Woody Grassland converted to Settlements	Organic soil	CH_4	1.112	1.112	0.630	0.630	41.120	258.591	261.840	0.000	0.000	0.000	0.001	0.000	0.000
4.(II).H.1	Woody Grassland converted to Settlements	Organic soil	N_2O	2.445	2.445	1.385	1.385	41.120	222.682	226.447	0.000	0.000	0.000	0.001	0.001	0.000
4.E.2.3.2	Woody Grassland converted to Settlements	Biomass	CO_2	145.162	145.162	134.818	134.818	41.120	44.169	60.347	0.004	0.000	0.001	0.002	0.057	0.003
4.(IV).2	Woody Grassland converted to Settlements	SOM_Mineral soil	N_2O	1.492	1.492	0.845	0.845	41.120	297.133	299.964	0.000	0.000	0.000	0.001	0.000	0.000
4.(III).E.2.3.2	Woody Grassland converted to Settlements	SOM_Mineral soil	N_2O	6.629	6.629	3.757	3.757	41.120	214.629	218.532	0.000	0.000	0.000	0.003	0.002	0.000
4.E.2.4.3	Other Wetlands converted to Settlements	Mineral soil	CO_2	10.070	10.070	21.203	21.203	47.461	47.631	67.240	0.000	0.000	0.000	0.004	0.010	0.000
4.E.2.4.3	Other Wetlands converted to Settlements	Organic soil	CO_2	0.000	0.000	0.000	0.000	47.461	55.354	72.915	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).H.1	Other Wetlands converted to Settlements	Organic soil	CH_4	0.000	0.000	0.000	0.000	47.461	258.591	262.911	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).H.1	Other Wetlands converted to Settlements	Organic soil	N_2O	0.000	0.000	0.000	0.000	47.461	222.682	227.684	0.000	0.000	0.000	0.000	0.000	0.000
4.E.2.4.3	Other Wetlands converted to Settlements	Biomass	CO_2	4.194	4.194	0.000	0.000	47.461	32.320	57.421	0.000	0.000	0.000	0.001	0.000	0.000
4.(IV).2	Other Wetlands converted to Settlements	SOM_Mineral soil	N_2O	0.187	0.187	0.395	0.395	47.461	294.942	298.736	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).E.2.4.3	Other Wetlands converted to Settlements	SOM_Mineral soil	N_2O	0.833	0.833	1.754	1.754	47.461	211.586	216.844	0.000	0.000	0.000	0.002	0.001	0.000
4.E.2.4.2	Flooded Land converted to Settlements	Mineral soil	CO_2	0.000	0.000	0.000	0.000	49.684	84.966	98.426	0.000	0.000	0.000	0.000	0.000	0.000
4.E.2.4.2	Flooded Land converted to Settlements	Organic soil	CO_2	30.631	30.631	16.636	16.636	49.684	55.354	74.382	0.000	0.000	0.000	0.004	0.009	0.000
4.(II).H.1	Flooded Land converted to Settlements	Organic soil	CH_4	0.649	0.649	0.353	0.353	49.684	258.591	263.321	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).H.1	Flooded Land converted to Settlements	Organic soil	N_2O	1.427	1.427	0.775	0.775	49.684	222.682	228.158	0.000	0.000	0.000	0.001	0.000	0.000
4.E.2.4.2	Flooded Land converted to Settlements	Biomass	CO_2	-29.504	29.504	-9.090	9.090	49.684	47.930	69.035	0.000	0.000	0.000	0.006	0.005	0.000
4.(IV).2	Flooded Land converted to Settlements	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	49.684	303.218	307.262	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).E.2.4.2	Flooded Land converted to Settlements	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	49.684	222.978	228.446	0.000	0.000	0.000	0.000	0.000	0.000
4.E.2.5	Other Land converted to Settlements	Mineral soil	CO_2	-4.605	4.605	-5.587	5.587	70.791	62.805	94.635	0.000	0.000	0.000	0.001	0.004	0.000
4.E.2.5	Other Land converted to Settlements	Organic soil	CO_2	0.000	0.000	0.000	0.000	70.791	55.354	89.863	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).H.1	Other Land converted to Settlements	Organic soil	CH_4	0.000	0.000	0.000	0.000	70.791	258.591	268.106	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).H.1	Other Land converted to Settlements	Organic soil	N_2O	0.000	0.000	0.000	0.000	70.791	222.682	233.664	0.000	0.000	0.000	0.000	0.000	0.000
4.E.2.5	Other Land converted to Settlements	Biomass	CO_2	-18.692	18.692	0.000	0.000	70.791	47.930	85.490	0.000	0.000	0.000	0.006	0.000	0.000
4.(IV).2	Other Land converted to Settlements	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	70.791	297.769	306.069	0.000	0.000	0.000	0.000	0.000	0.000
4.(III).E.2.5	Other Land converted to Settlements	SOM_Mineral soil	N_2O	0.000	0.000	0.000	0.000	70.791	215.510	226.839	0.000	0.000	0.000	0.000	0.000	0.000
4.F.1	Other Land remaining Other Land	Mineral soil	CO_2	0.000	0.000	0.000	0.000	42.315	92.858	102.045	0.000	0.000	0.000	0.000	0.000	0.000
4.F.1	Other Land remaining Other Land	Organic soil	CO_2	0.000	0.000	0.000	0.000	42.315	0.000	42.315	0.000	0.000	0.000	0.000	0.000	0.000
4.(II).H.2	Other Land remaining Other Land	Organic soil	CH_4	0.000	0.000	0.000	0.000	42.315	0.000	42.315	0.000	0.000	0.000	0.000	0.000	0.000

	A		B	C		D		E	F	G	H	I	J	K	L	M
	Category	Pool	Gas	Base year emissions [CO_2-eq.] [Gg a^{-1}]	Base year emissions; contribution in [CO_2-eq.] [Gg a^{-1}]	Year 2013 emissions [CO_2-eq.] [Gg a^{-1}]	Year 2013 emissions; contribution in [CO_2-eq.] [Gg a^{-1}]	Activity data uncertainty (half the 95% confidence interval) [%]	Emission factor uncertainty (half the 95% confidence interval) [%]	Combined uncertainty (half the 95% confidence interval) [%]	Contribution to Variance by Category in Year t [%]	Type A sensitivity [%]	Type B sensitivity [%]	Uncertainty in trend in national emissions introduced by emission factor uncertainty [%]	Uncertainty in trend in national emissions introduced by activity data uncertainty [%]	Uncertainty introduced into the trend in total national emissions [%]
4.(II).H.2	Other Land remaining Other Land	Organic soil	N_2O	0.000	0.000	0.000	0.000	42.315	0.000	42.315	0.000	0.000	0.000	0.000	0.000	0.000
4.F.1	Other Land remaining Other Land	Biomass	CO_2	0.000	0.000	0.000	0.000	42.315	0.000	42.315	0.000	0.000	0.000	0.000	0.000	0.000
	Total				136,976.097		122,024.536			∑ H	524.697				∑ M	23.254
	Total uncertainty		**Emission level$_{[root \sum H]}$**				**22.906 %**					**Emission trend$_{[root \sum M]}$**				**4.822 %**

19.5 Other detailed methodological descriptions for the source category "Waste and wastewater" (6)

20 ANNEX 4: THE CO_2 REFERENCE APPROACH, A COMPARISON OF THAT APPROACH WITH THE SECTORAL APPROACH, AND RELEVANT INFORMATION ON THE NATIONAL ENERGY BALANCE

General information

In general, the Reference Approach should lend itself to use by all reporting parties. Such generalization and abstraction cannot help but lead to considerable discrepancies with the Sectoral Approach.

Overall, the Sectoral Approach makes it possible to carry out calculations that are considerably more differentiated, realistic and precise, and the detailed results it produces often differ sharply from those produced under the Reference Approach.

Efforts to eliminate errors in transfer of country-specific activity data into the Reference Approach structure have gotten underway in recent years. At the level of maximum aggregation, this work, which is being continued with the present submission, has brought the results achieved with the two calculation approaches into excellent agreement (cf. Chapter 3.2.1.1). On the other hand, a number of discrepancies at the fuel and fuel-group levels still persist. While these can be explained – at least in part – as the result of country-specific circumstances, it has not yet been possible to eliminate them in a satisfactory manner.

The Reference Approach will thus continue to offer room for further improvements. Notably, the comparability of the two approaches would benefit from extensive flexibilization of data management in the CRF Reporter, as well as from review, and any necessary revision, of the input data and calculation approaches used for the area of non-energy-related consumption.

20.1 Comparing the results: The Sectoral Approach and the Reference Approach

The following section compares results obtained in calculating CO_2 emissions via the Sectoral Approach with results obtained via the Reference Approach.

CO_2 emissions were determined with the Sectoral Approach (1.AA; sector-specific results) and with the Reference Approach (1.AB; pursuant to (IPCC, 2006)). The Reference Approach makes use of primary data relative to production, imports and exports of fuels, as well as of data on changes in stocks, that are taken directly from the National Energy Balances of the Working Group on Energy Balances (AGEB, 2014).

As with the Sectoral Approach, complete oxidation is assumed. In conformance with (IPCC, 2006), the carbon emission factors used are equivalent to those of the Sectoral Approach and thus comprise nationally referenced values. The so-calculated CO_2 emissions data are used for verification of the Sectoral Approach.

CRF report table 1.A(c) compares results obtained with the Sectoral Approach with results obtained with the Reference Approach. Since the non-energy-related consumption (NEV) of the fuels considered occurs elsewhere (industrial processes and product use), the quantities that must be assigned to such consumption, pursuant to the Energy Balances, are deducted from the Reference Approach. In addition to lubricants, bitumen and naphtha, this procedure is applied to diesel fuel, light and heavy fuel oil, LPG, petroleum coke and other oils, hard coal and lignite, coke and natural gas. For 2013, this approach yields an NEV of about 1,000 petajoules (cf. CRF Table 1.A(c)).

In the current version of the CRF Reporter, Table 1.A(c) shows no emissions from combustion of fossil waste. To enable a useful comparison of the Sectoral Approach and the Reference Approach nevertheless, such emissions have been placed, within the software, in the category "Other fossil fuels" *("Andere fossile Brennstoffe")*. In CRF Table 1.A(b), therefore, "Waste (non-biomass fraction)" *("Abfall (nicht-biogener Anteil)")* is marked solely with notation key IE (included elsewhere: *"an anderer Stelle enthalten"*).

As a result, under "Other fossil fuels" the Reference Approach takes account only of the fossil fraction of the waste. Consequently, the pertinent input quantities and the emissions differ considerably from those determined via the Sectoral Approach. In light of the discrepancies in fuel allocation, no further harmonisation of the results seems feasible at present.

By contrast, in the case of peat, which is being listed separately for the first time, identical emission factors and input quantities are used. Table 1.A(c) thus shows only minimal differences – due probably to rounding – between the two sets of results.

The following tables and figures present further examples of the comparison between the Sectoral Approach and the Reference Approach. For 2013, the Reference Approach yields fuel inputs that are 1.52 % higher and emissions that are 0.73 % lower (cf. Chapter 3.2.1.1). Throughout the 1990-2013 period, almost all of the fuel inputs listed under the Reference Approach are higher than those listed under the Sectoral Approach.

Table 427: Comparison of the energy inputs determined via the Sectoral Approach (1.AA) and Reference Approach (1.AB) (boldface: maximum positive and negative discrepancies)

Year	1.AA	1.AB		1.AB (not including non-energy-related consumption = NEV) minus 1.AA	
		with NEV	without NEV		
	[PJ]				[%]
1990	11,686	12,980	11,864	177	1.52%
1991	11,525	12,706	11,657	131	1.14%
1992	11,066	12,275	11,217	150	1.36%
1993	11,077	12,278	11,251	175	1.58%
1994	10,882	12,144	11,031	149	1.37%
1995	10,958	12,145	11,044	86	0.79%
1996	11,373	12,559	11,466	93	0.82%
1997	10,963	12,242	11,081	117	1.07%
1998	10,917	12,198	11,015	98	0.89%
1999	10,613	11,867	10,720	107	1.01%
2000	10,557	11,875	10,641	84	0.80%
2001	10,840	12,127	10,949	109	1.00%
2002	10,619	11,939	10,757	139	1.30%
2003	10,613	12,049	10,856	242	2.28%
2004	10,412	11,876	10,663	251	2.41%
2005	10,189	11,744	10,469	280	**2.74%**
2006	10,330	11,830	10,601	271	2.63%
2007	9,902	11,292	10,123	221	2.23%
2008	10,064	11,363	10,218	154	1.53%
2009	9,405	10,590	9,535	130	1.38%
2010	9,871	11,016	9,840	-31	**-0.31%**
2011	9,530	10,677	9,528	-2	-0.02%
2012	9,567	10,732	9,628	61	0.64%
2013	9,905	11,092	10,055	150	1.52%

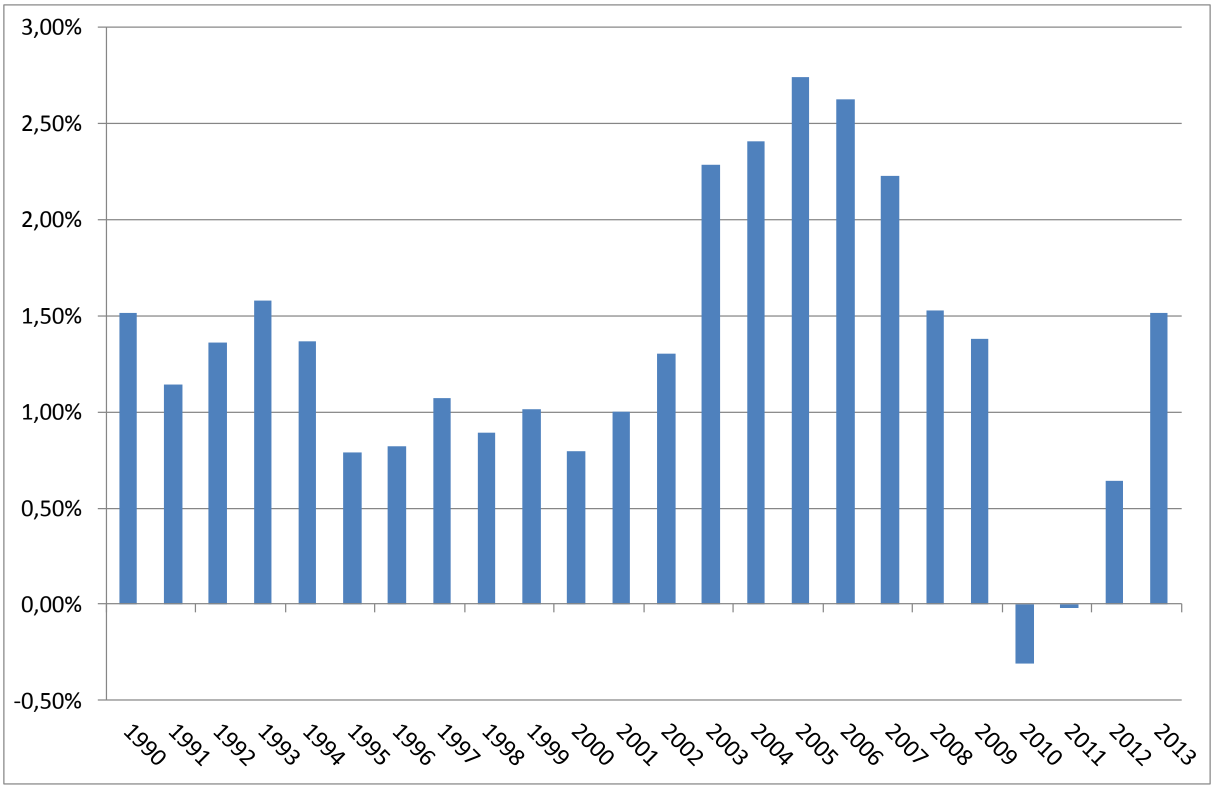

Figure 86: Percentage discrepancies between annual total activity data under the Reference Approach and the corresponding total quantities under the Sectoral Approach

The results are less clear-cut for the carbon dioxide emissions calculated with the Reference Approach. Nonetheless, those emissions tend to be lower, in absolute terms, than those calculated with the Sectoral Approach.

Table 428: Comparison of the CO_2 emissions determined via the Sectoral Approach (1.AA) and Reference Approach (1.AB; not including non-energy-related consumption (NEV))) (boldface: maximum positive and negative discrepancies)

Year	1.AA	1.AB (not including NEV)	1.AB (not including NEV) minus 1.AA	
	[kt CO_2]			[%]
1990	985,867	999,162	13,296	**1.35%**
1991	951,954	954,897	2,943	0.31%
1992	906,657	905,909	-748	-0.08%
1993	896,998	897,555	557	0.06%
1994	878,289	876,494	-1,794	-0.20%
1995	877,696	865,638	-12,058	-1.37%
1996	899,832	890,035	-9,797	-1.09%
1997	869,447	860,738	-8,709	-1.00%
1998	862,825	852,941	-9,884	-1.15%
1999	837,605	829,154	-8,451	-1.01%
2000	836,484	826,012	-10,472	-1.25%
2001	858,888	847,936	-10,952	-1.28%
2002	844,185	837,610	-6,574	-0.78%
2003	841,143	844,463	3,320	0.39%
2004	826,422	828,067	1,644	0.20%
2005	808,465	807,918	-547	-0.07%
2006	819,393	818,589	-804	-0.10%
2007	793,632	789,557	-4,076	-0.51%
2008	799,216	791,557	-7,659	-0.96%
2009	742,989	736,628	-6,362	-0.86%

Year	1.AA	1.AB (not including NEV)	1.AB (not including NEV) minus 1.AA	
	[kt CO_2]			[%]
2010	781,686	762,698	-18,988	**-2.43%**
2011	760,138	744,818	-15,320	-2.02%
2012	766,205	753,564	-12,641	-1.65%
2013	789,610	783,883	-5,727	-0.73%

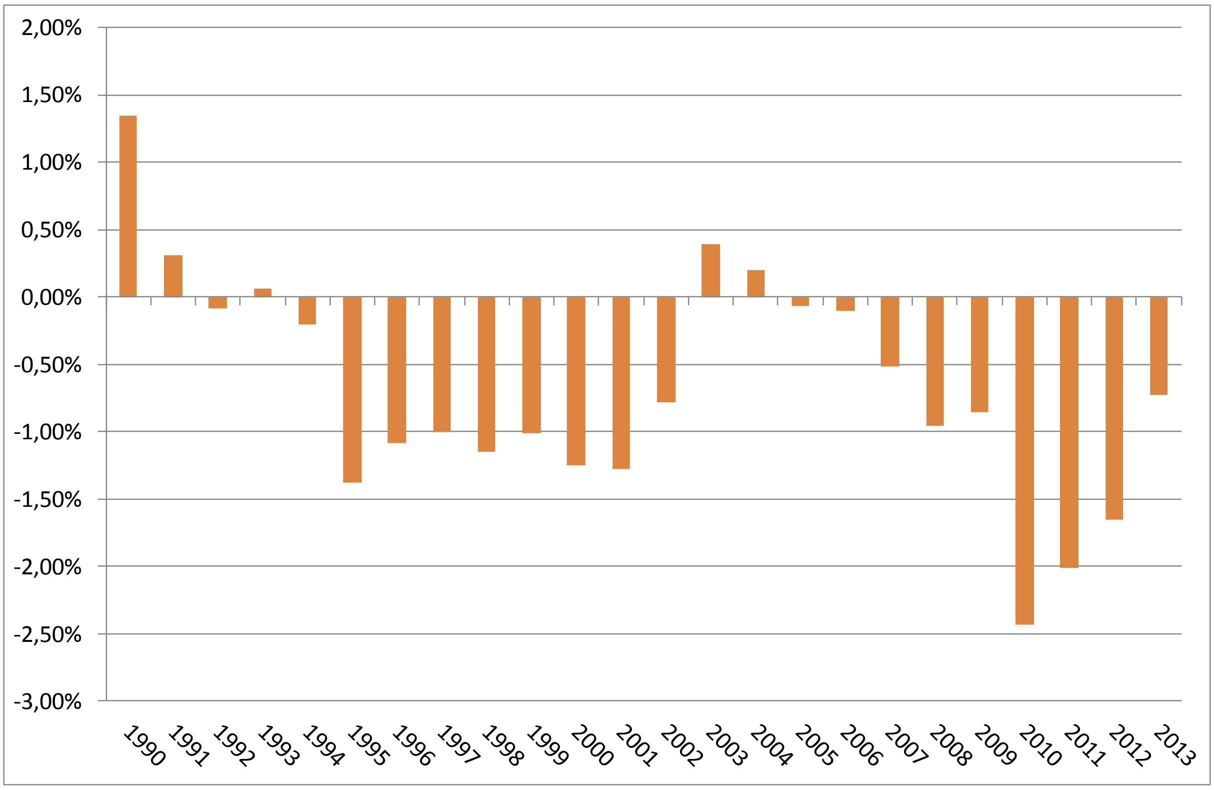

Figure 87: Percentage discrepancies between the annual carbon dioxide emissions as calculated with the Reference Approach and as calculated with the Sectoral Approach

21 ANNEX 5: ASSESSMENT OF COMPLETENESS, AND ASSESSMENT OF POTENTIALLY EXCLUDED SOURCES AND SINKS OF GREENHOUSE GAS EMISSIONS

The following three tables show the sources for greenhouse gases that have not been included in Germany's greenhouse-gas inventories to date. The tables also include explanations of the reasons for such omission. This table is a summary of CRF Table 9(a), which contains a more detailed overview of non-included sources and sinks. Additional information is presented in Chapter 1.8. In accordance with the new definition of the notation key „NE“ a few new small NE-categories have been elected. The following table describes that both limit values (0,05 % of national total GHG-emissions for the single category and 0,1 % for the sum of the elected categories) have been taken into account. More details are provided in the relevant category-specific chapters.

Tabelle 429: Quantitative assessment of potentially excluded sources and sinks

Emissions year X-1*		
kt CO_2 equiv	national total (without LULUCF)	952.460,45
kt CO_2 equiv	thereoff 0,1 %	952,46
kt CO_2 equiv	thereoff 0,05 %	476,23
Source category code	**Source category description**	**assumption for estimated emission (in kt $CO2_{equi.}$)**
1.B.2.d	Geothermal Energy	< 1
1.C	CO_2 Transport and Storage	70
2.A.4.c	Non-metallurgical magnesium production	158
2.B.6	Titan dioxid production	228
2.D.3	Asphalt - asphalt roofing	0,2
2.D.3	Asphalt - road paving	2,5
2.E.4	Semiconductor production	0,0465
3.A.4	Deer	132,25
3.A.4	Rabbits	3,69
3.A.4	Fur-bearing animals	0,16
3.B(a).4	Deer	1,45
3.B(a).4	Fur-bearing animals	1,08
3.B(a).4	Rabbits	0,88
3.B(a).4	Ostrich	1,08
3.B(b).4	Deer	IE
3.B(b).4	Fur-bearing animals	1,77
3.B(b).4	Rabbits	2,14
3.B(b).4	Ostrich	0,06
3.B(b).5	Indirect emissions	1,02
3.D	Direct and indirect N2O emissions from Agricultural Soils	28,35
5.A	Flaring	0,0006
	Total	**632,68**

* Ref. to year X instead du to change in methodology from subm. 2014 to 2015

Table 430: Overview, for completeness, of sources and sinks whose emissions are not estimated (NE)

Source/sink category	GHG	Allocation used by the Party / Explanation
1.B Fugitive Emissions from Fuels / 1.B.2.d Other - Geothermal	CO2,CH4, N2O	Considered insignificant according to new definition of NE
2.A Mineral Industry/2.A.4.c Non metallurgical magnesia production	CO2	Considered insignificant according to new definition of NE
2.B Chemical Industry/2.B.6 Titanium Dioxide Production	CO2	Considered insignificant according to new definition of NE
2.D Non-energy Products from Fuels and Solvent Use/2.D.3 Other (please specify)/Asphalt roofing	CO2	Indirect CO2 from NMVOC is considered insignificant according to new definition of NE
2.D Non-energy Products from Fuels and Solvent Use/2.D.3 Other (please specify)/Road paving with asphalt	CO2	Indirect CO2 from NMVOC is considered insignificant according to new definition of NE
2.E Electronics Industry/2.E.4 Heat Transfer Fluid 2.E Electronics Industry/2.E.4 Heat Transfer Fluid/C6F14	C6F14	Emissions are according to definition below threshold and are negligible.
3.1 Livestock/3.A Enteric Fermentation/3.A.4 Other livestock/Deer	CH4	Considered insignificant according to new definition of NE
3.1 Livestock/3.A Enteric Fermentation/3.A.4 Other livestock/Other (please specify)/Fur-bearing Animals, Ostrich, Rabbit	CH4	Considered insignificant according to new definition of NE
3.1 Livestock/3.B Manure Management/3.B.1 CH4 Emissions/3.B.1.4 Other livestock/Deer	CH4	Considered insignificant according to new definition of NE
3.1 Livestock/3.B Manure Management/3.B.1 CH4 Emissions/3.B.1.4 Other livestock/Other (please specify)/Fur-bearing Animals, Ostrich, Rabbit	CH4	Considered insignificant according to new definition of NE
3.1 Livestock/3.B Manure Management/3.B.2 N2O and NMVOC Emissions/3.B.2.4 Other livestock/Deer	N2O	Considered insignificant according to new definition of NE
3.1 Livestock/3.B Manure Management/3.B.2 N2O and NMVOC Emissions/3.B.2.4 Other livestock/Other (please specify)/Fur-bearing Animals, Ostrich, Rabbit	N2O	Considered insignificant according to new definition of NE
5.A.1.a Solid Waste Disposal / Managed Waste Disposal Sites / Anaerobic CH4 & N2O from flaring	CH4, N2O	Considered insignificant according to new definition of NE

Table 431: Overview, for completeness, of sources and sinks that are reported elsewhere (included elswhere, IE)

Source/sink category	GHG	Allocation used by the Party / Explanation
1.AA Fuel Combustion - Sectoral approach/1.A.2 Manufacturing Industries and Construction/1.A.2.a Iron and Steel/Biomass	CO2	Emissions are part of the carbon balance and were reported under blast furnace gas incineration (solid fuels).
1.AA Fuel Combustion - Sectoral approach/1.A.2 Manufacturing Industries and Construction/1.A.2.a Iron and Steel/Other Fossil Fuels	CO2	Emissions are part of the carbon balance and were reported under blast furnace gas incineration (solid fuels).
1.AA Fuel Combustion - Sectoral approach/1.A.2 Manufacturing Industries and Construction/1.A.2.c Chemicals/All Fuels	CH4, CO2, N2O	reported in source category 1.A.2.g viii
1.AA Fuel Combustion - Sectoral approach/1.A.2 Manufacturing Industries and Construction/1.A.2.d Pulp, Paper and Print/All Fuels	CH4, CO2, N2O	reported in source category 1.A.2.g viii
2.A Mineral Industry/2.A.4 Other Process Uses of Carbonates/2.A.4.d Other	CO, CO2, NMVOC, NOx	all carbonate using activities are described in NIR
2.B Chemical Industry/2.B.10 Other (please specify)/Other	N2O	Is reported at 2G3a medical applications.

Source/sink category	GHG	Allocation used by the Party / Explanation
2.B Chemical Industry/2.B.8 Petrochemical and Carbon Black Production/2.B.8.a Methanol	CH4, CO2	aggregated with Emission data of 2.B.8.b-e and reported under 2.B.8.g. Petrochemicals.
2.B Chemical Industry/2.B.8 Petrochemical and Carbon Black Production/2.B.8.b Ethylene	CH4, CO2	aggregated with emission data of 2.B.8.a, c-e and reported under 2.B.8.g. Petrochemicals.
2.B Chemical Industry/2.B.8 Petrochemical and Carbon Black Production/2.B.8.c Ethylene Dichloride and Vinyl Chloride Monomer	CH4, CO2	aggregated with emission data of 2.B.8.a-b, d-e and reported under 2.B.8.g. Petrochemicals.
2.B Chemical Industry/2.B.8 Petrochemical and Carbon Black Production/2.B.8.d Ethylene Oxide	CH4, CO2	aggregated with emission data of 2.B.8.a-c,e and reported under 2.B.8.g. Petrochemicals.
2.B Chemical Industry/2.B.8 Petrochemical and Carbon Black Production/2.B.8.e Acrylonitrile	CH4, CO2	aggregated with emission data of 2.B.8.a-d and reported under 2.B.8.g. Petrochemicals.
2.C Metal Industry/2.C.1 Iron and Steel Production/2.C.1.c Direct Reduced Iron	CO2	is considered in 2C1a
2.C Metal Industry/2.C.1 Iron and Steel Production/2.C.1.d Sinter	CH4, CO2	is considered in 1A2
2.G Other Product Manufacture and Use/2.G.2 SF6 and PFCs from Other Product Use/2.G.2.d Adiabatic Properties: Shoes and Tyres/SF6	SF6	Emissions "from manufacturing" and "from stocks" are reported at "from disposal".
3.1 Livestock/3.A Enteric Fermentation/3.A.4 Other livestock/Buffalo	CH4	before 1996: NO, included in cattle
3.1 Livestock/3.A Enteric Fermentation/3.A.4 Other livestock/Mules and Asses	CH4	considered under horses
3.1 Livestock/3.B Manure Management/3.B.1 CH4 Emissions/3.B.1.4 Other livestock/Buffalo	CH4	before 1996: NO, IE: considered in cattle
3.1 Livestock/3.B Manure Management/3.B.1 CH4 Emissions/3.B.1.4 Other livestock/Mules and Asses	CH4	IE: considered under horses
3.1 Livestock/3.B Manure Management/3.B.2 N2O and NMVOC Emissions/3.B.2.4 Other livestock/Buffalo	N2O	before 1996: NO, included in non-dairy cattle
3.1 Livestock/3.B Manure Management/3.B.2 N2O and NMVOC Emissions/3.B.2.4 Other livestock/Mules and Asses	N2O	included under horses
3.G Liming/3.G.2 Dolomite CaMg(CO3)2	CO2	Data cannot be differentiated with regard to types of application (dolomite or lime) dolomite use is included in limestone use.
4(IV) Indirect N2O Emissions from Managed Soils/Atmospheric Deposition	N2O	is included under 3.B.2.5 Indirect N2O Emissions (Agriculture)
4.A Forest Land/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Total Organic Soils/Drained Organic Soils	CO2	included under CRF 4A
4.A Forest Land/4.A.2 Land Converted to Forest Land	CO, NOx	included in A1 Forest land remaining Forest Land, Wildfires
4.C Grassland/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Total Organic Soils/Drained Organic Soils	CO2	see NIR chapter 6.1.2.2.2 and 6.4.2.7.2
4.D Wetlands/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Flooded Lands/Total Organic Soils/Drained Organic Soils	CH4, N2O	IE under other
4.D Wetlands/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Other Wetlands (please specify)/Other	CO2	IE in carbon stock change
4.D Wetlands/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Peat Extraction Lands/Total Organic Soils/Rewetted Organic Soils	CO2, N2O	IE: included in carbon stock change
4.G Harvested Wood Products/Approach B/Approach B2/Total HWP from Domestic Harvest/HWP Produced and Consumed Domestically/Solid Wood	CO2	IE under Other, sum of sawnwood and wood panels

Source/sink category	GHG	Allocation used by the Party / Explanation
4.H Other (please specify)/Grassland 4.H Other (please specify)/Grassland/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CH4	IE: CH4 emissions and removals from drainage and rewetting
4.H Other (please specify)/Settlements 4.H Other (please specify)/Settlements/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CO2	IE under carbon stock change

22 ANNEX 6: ADDITIONAL INFORMATION TO BE CONSIDERED AS PART OF THE NIR SUBMISSION (WHERE RELEVANT) OR OTHER USEFUL REFERENCE INFORMATION

22.1 Additional information relative to inventory preparation and to the National System

22.1.1 Definitions in the "National System" principles paper on emissions reporting

In the "National System" principles paper on emissions reporting, state secretaries of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB); Federal Ministry of the Interior (BMI); Federal Ministry of Defence (BMVg); Federal Ministry of Finance (BMF); Federal Ministry for Economic Affairs and Energy (BMWi); Federal Ministry of Transport, Building and Urban Affairs (BMVBS) and Federal Ministry of Food and Agriculture (BMEL) defined responsibilities pertaining to the various relevant source and sink categories and to the necessary financing for 2008. The agreement reads as follows:

BMUB, BMI, BMVg, BMF, BMWi, BMVBS, BMEL Berlin, 5 June 2007

"National System" principles paper on emissions reporting

The state secretaries of the ministries concerned have determined as follows, by common consent, with regard to the issue of the "National System" for emissions reporting pursuant to Art. 5(1) Kyoto Protocol:

1. *The Federal Environmental Agency, Section I 4.6[173] "Emissions Situation", is the responsible "Single national entity" (national co-ordinating agency) for reporting pursuant to the UN Framework Convention on Climate Change and the Kyoto Protocol. A country's Single National Entity is responsible for preparing the country's national inventory, working for continual improvement of the inventory, supporting those persons involved in the national system and preparing decisions of the Co-ordinating Committee.*

2. *A Co-ordinating Committee, representing all affected departments, has been established to deal with all questions arising in the framework of the National System, and to be responsible for official discussion and approval of the inventories and the reports required pursuant to Articles 5, 7 and 8 of the Kyoto Protocol. The Committee shall support all pertinent processes in this framework and, in particular, it shall clarify any pertinent uncertainties – for example, in connection with definition of individual emission factors.*

   In particular, the Committee shall define key source and sink categories, and the minimum requirements pertaining to quality control and quality assurance for data collection and processing and to the annual quality control and quality assurance plan.

   As necessary, the Committee may specify the methods to be used for calculating emissions in the various categories and for calculating storage in sink categories. The Committee is chaired by the BMUB. The Committee shall meet whenever at least one department sees a need for such a meeting. Subordinate authorities and other institutions involved in inventory preparation may be included in meetings as necessary.

[173] Author's remark: currently, I 2.6.

3. *For preparation of the national inventory, such data shall be used, for calculations of emissions and reductions, as are required pursuant to the provisions of Art. 3 (1) of decision 280/2004/EC and of Art. 2 (1) of the Ground rules for calculating emissions in source categories and storage in sink categories. Inventories shall be prepared on an annual basis. In addition, quality assurance in keeping with the requirements of Art. 12 of the rules shall be carried out. Furthermore, reliable documentation and archiving shall be required.*

   Existing data-transfer arrangements, such as those made on the basis of voluntary agreements or legal provisions, should not be fundamentally changed; they should only be completed and improved as necessary in order to provide a reliable database. For this reason, the aforementioned responsibilities do not necessarily include data collection and forwarding. With regard to division of responsibilities between BMUB/UBA, BMVBS and BMWI, attention is called especially to Annex 1.

   The responsibilities for ensuring proper data delivery to the Single National Entity, and for quality control, documentation and data archiving, shall be distributed as follows among the various relevant departments:

   a) For category 1 (Energy) – with the exception of categories 1.A.3 (Transport) und 1.A.5a (Energy: other), where emissions sources of the German Federal Armed Forces (Bundeswehr) are concerned – the Federal Ministry for Economic Affairs and Energy (BMWi) has responsibility.

   b) For categories 2 (Production processes) and 3 (Use of solvents and other products), the Federal Ministry for Economic Affairs and Energy (BMWi) has responsibility.

   c) For category 1.A.3 (Transport), the Federal Ministry of Transport, Building and Urban Affairs (BMVBS) has responsibility.

   d) For category 1.A.5a (Energy: other), where emissions sources of the German Federal Armed Forces (Bundeswehr) are concerned – the Federal Ministry of Defence (BMVg) has responsibility. Where data are subject to secrecy provisions, the Federal Environment Agency shall take the relevant secrecy requirements into account.

   e) For source and sink categories 4 (Agriculture) and 5 (Land use, land-use changes and forestry), the Federal Ministry of Food and Agriculture (BMEL) has responsibility.

   f) For category 6 (Waste) and category 7, and well as for issues related to greenhouse-gas emissions from biomass combustion, the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) has responsibility.

   g) The Federal Ministry of Food and Agriculture (BMEL) is also responsible for preparing tables in the standardised reporting format pursuant to Art. 2 (2) letter a of Decision 2005/166/EC (implementation rules) in source and sink categories 4 and 5.

   In addition, the relevant authorities, as determined by the pertinent statistics regulations, are responsible for tasks relative to official statistics, including data delivery, quality assurance and data documentation and archiving. Co-operation between a) the statistical offices of the Federal Government and the Länder and b) the agencies concerned with reporting is co-ordinated via the Federal Statistical Office. In the process, secrecy requirements pertaining to statistics are to be observed.

4. *The responsible departments shall clarify, in the short term, how proper data provision is to be permanently assured, to the extent such clarification has not already been completed. In*

particular, this requirement shall apply to agreements, ordinances or laws needed for institutionalisation of the National System. In general, for purposes of emissions reporting, voluntary agreements with associations and/or individual companies shall have the same status as pertinent legal provisions. In addition, as agreed in the co-ordination discussion on 12 September 2006, the Federal Environment Agency and the Federal Statistical Office shall determine what data can be provided, for reporting purposes, from the official statistical system, as well as what additional data should be collected via the official statistical system. The various relevant departments, the Federal Environment Agency and the Federal Statistical Office shall send their pertinent proposals to the BMUB by 15 July 2007.

5. *By 31 July 2007, the BMUB shall invite participating departments to co-ordinate pertinent proposals and to establish a schedule for implementing the required instruments. The responsible departments, and the Federal Government, shall arrange for the establishment of the required instruments as quickly as possible.*

6. *Where additional funding is required for execution of the responsibilities mentioned under 3., such funding shall be provided from proceeds from sale of AAUs, via an expansion of the state secretaries' agreement of 22 December 2006 relative to Article 3.4 of the Kyoto Protocol.*

   To this end, a budget item for relevant income shall be established within Individual Plan 16 (Einzelplan 16) as of the 2008 fiscal year. Following review by the Federal Ministry of Finance (BMF), the additional requirements requiring financing shall be listed as expenditures within the departments' individual budgets. The departments' additional requirements in this regard must be submitted to the BMF by 6 June 2007.

   Should additional budget funding be required in coming years, in addition to the additional requirements determined in connection with the 2008 budget, then suitable relevant amounts of additional AAUs shall be sold in subsequent years.

[…]

Annex: Division of responsibilities between BMUB/UBA, BMVBS and BMWI

The BMUB, BMVBS and BMWi have agreed that the existing emissions-reporting structures are to be retained and that the Federal Environment Agency (UBA) shall continue to perform its existing tasks with regard to the categories 1, 1.A.3, 2 and 3. The BMVBS and the BMWi shall ensure that any gaps in the data for those categories for which they are responsible are closed.

Specifically:

BMWi:

With regard to category 1: The inventories in this area shall be prepared by the Federal Environment Agency, on a basis that shall include energy data provided by the agency contracted by the BMWi for preparation of energy balances, as well as on the basis of additional relevant statistics and association information.

With regard to category 2: The inventories in this area shall be produced by the Federal Environment Agency on the basis of data that shall include data from statistics of the manufacturing sector (Produzierendes Gewerbe – ProdGewStatG) and from communications of relevant associations / individual companies.

With regard to category 3: The inventories in this area shall be produced by the Federal Environment Agency on the basis of data that shall include data from statistics of the manufacturing sector

(Produzierendes Gewerbe – ProdGewStatG), from foreign trade statistics and from communications of relevant associations / individual companies.

Existing requirements for further optimisation shall be clarified, in the short term, by BMWi, BMUB and UBA, working in co-ordination. Where data optimisation is required via changes in existing surveys based on the Environmental Statistics Act (UStatG) or on the 13th Ordinance on the Execution of the Federal Immission Control Act (13. BimSchV), the BMUB shall be responsible. The Federal Environment Agency shall assume responsibility for recording and archiving data received by the Federal Environment Agency.

BMVBS:

Emissions relative to category 1.A.3 (Transport) shall be calculated by the Federal Environment Agency, using the TREMOD model. The BMVBS shall provide data/calculations as needed to close data gaps and determine emissions relative to international air transports or shall ensure that such data/calculations are provided by third parties. At present, emissions from ship transports may be calculated from Energy Balance data, using default emission factors. The Federal Environment Agency shall assume responsibility for recording and archiving data received by the Federal Environment Agency.

22.1.2 Additional information about the Quality System of Emissions Inventories

22.1.2.1 Minimum requirements pertaining to a system for quality control and assurance

As described above in the main section, the requirements pertaining to the system for quality control and quality assurance (QC/QA system) and to measures for quality control and quality assurance are defined primarily by Chapter 8 of the *IPCC Good Practice Guidance*.

From those provisions, the Federal Environment Agency has derived its own "General minimum requirements pertaining to quality control and quality assurance in connection with greenhouse-gas-emissions reporting" ("Allgemeine Mindestanforderungen an die Qualitätskontrolle und Qualitätssicherung bei der Treibhausgasemissionsberichterstattung"; last revision: November 2007). These are described below.

22.1.2.1.1 Introduction

Representatives of the departments participating in the co-ordinating committee for the National System of Emissions Inventories define the general minimum requirements, which are described in the present document, for quality control and quality assurance (QC/QA) in reporting on greenhouse-gas emissions. Such minimum requirements serve as the basis for collection, processing and forwarding of, and reporting on, all data that support the process of reporting on greenhouse-gas emissions.

These minimum QC/QA requirements must be adhered to on all levels of inventory preparation. In many cases, relevant efforts can draw on existing processes and systems, such as the quality standards for public statistics. Annex 1 of the present document describes, by way of example, implementation of the minimum QC/QA requirements and the QC/QA system within the Federal Environment Agency. All participating institutions are required to submit suitable descriptions of their implementation of these minimum requirements; such descriptions are to be published with the inventory report in the framework of reporting in 2009.

On request, the Federal Environment Agency supports participating ministries in preparing QC/QA systems in their relevant areas of responsibility.

22.1.2.1.2 System for quality control and quality assurance

The *rules (Commission Decision 2005/166/EC) implementing Decision 280/2004/EC* require national greenhouse-gas inventories to conform to the QC/QA requirements of the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC Good Practice Guidance) and the *IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC Good Practice Guidance for LULUCF).

The *IPCC Good Practice Guidance* specifies that QC/QA systems must be introduced, with the aim of enhancing transparency, consistency, comparability, completeness and precision of national emissions inventories and, especially, that such inventories must fulfill requirements pertaining to "good inventory practice". A QC/QA system comprises the following:

- An agency responsible for co-ordinating QC/QA activities
- Development and implementation of a QC/QA plan
- General QC procedures
- Category-specific QC procedures
- QA procedures and
- Reporting procedures
- Documentation and archiving procedures

QC/QA measures can conflict with requirements for punctuality and cost-effectiveness. Available time, and available staffing and financial resources, should thus be taken into account in any QC/QA-system development. In good practice, more stringent data-quality requirements are applied to key categories. For other categories, not all category-specific QC procedures have to be implemented. In addition, not all measures have to be carried out on an annual basis; for example, data-collection methods have to be reviewed only once in detail. Thereafter, it suffices to carry out periodic controls to determine whether the prerequisites for application of relevant methods are still being fulfilled. Data uncertainty is another factor that enters into requirements pertaining to QC/QA measures. In order to reduce an inventory's overall uncertainty, those categories that have high levels of uncertainty should be reviewed in detail.

22.1.2.1.3 Agency responsible for co-ordinating QC/QA activities

As the Single National Entity (national co-ordinating agency), the Federal Environment Agency is responsible for the QC/QA system for the national greenhouse-gas inventory. In this function, it has established the position of co-ordinator for the Quality System for Emissions Inventories (QSE). In good practice, each company and organisation involved in inventory preparation appoints a QC/QA co-ordinator and notifies the QSE co-ordinator of such appointment.

A QC/QA co-ordinator has responsibility for ensuring that a relevant QC/QA system is developed and implemented. Such implementation should be suitably institutionalised – for example, by means of an in-house directive or association agreement.

In order to ensure that the Single National Entity can efficiently carry out its supporting tasks, the persons responsible for the following additional functions should be announced (by name) to the QSE co-ordinator:

Responsible expert (Fachverantwortlicher) – Person responsible for data collection, data entry and pertinent calculation, in keeping with the prescribed methods, as well as for carrying out QC measures and preparing a relevant textual contribution for the National Inventory Report.

Quality control manager (Qualitätskontrollverantwortlicher) – Person responsible for checking and approving data and report sections (the QC/QA co-ordinator may also perform this function).

22.1.2.1.4 QC/QA plan

The purpose of the QC/QA plan is to ensure that QC/QA measures are properly organised and executed. It includes a description of all required QC/QA measures and a schedule for implementation of such measures. The QC/QA plan also defines the primary emphases of such measures. The criteria for selection of categories for detailed review include the following:

- The category's relevance (key category yes/no, uncertainties high/low)
- The time of the last detailed QC/QA measure for the source category, and the results of such measure
- Changes in methods or the pertinent database
- Results of annual inventory review in keeping with the UN Framework Convention on Climate Change and the Kyoto Protocol
- Available resources for execution of QC/QA measures

Good practice calls for establishing a QC/QA plan and then reviewing and updating it each year after the latest inventory has been prepared.

On the basis of the results of annual inventory review, and of the results of QC/QA measures of which it is aware, the Single National Entity prepares an improvement plan for the entire inventory. On this basis, in turn, it derives proposals for a binding inventory plan for the next report year. Such proposals are then submitted to the co-ordinating committee for approval. The QC/QA co-ordinator, working in co-operation with the QSE co-ordinator in the Single National Entity, defines the procedures, scheduling and scope for inclusion of his institution's QC/QA measures in the inventory plan for the overall inventory.

22.1.2.1.5 General quality control

Pursuant to the definition used by the IPCC (Chapter 8.1 *Good Practice Guidance*), quality control (QC) comprises a system of routine specialised measures for measuring and checking the quality of inventories in preparation.

Consequently, a QC system should achieve the following:

- Facilitate routine, standardised checks in the interest of data integrity, correctness and completeness;
- Identify and eliminate errors and omissions;
- List and archive inventory material and record all QC activities.

Table 8.1 of the *IPCC Good Practice Guidance* includes a complete list of general QC measures. Requirements pertaining to general, Tier-1 QC procedures can be derived from the requirements mentioned in Chapter 8.6 of the *IPCC Good Practice Guidance*. Typical general quality control measures in activity-rate determination include checking data for transfer errors, checking data for completeness, checking formulae for combining data and carrying out plausibility checks with the help of external data sources and earlier calculations. Suppliers of emissions calculations have to carry out additional QC measures – for example, checking formulae for emissions calculation.

Required quality controls should be recorded in checklists. Such lists should include at least the checking measures carried out, the results of checking, any pertinent corrections made and the name of the person(s) responsible for the measures. Annex 2 of the present document includes a sample checklist of the Federal Environment Agency.

Not all quality controls have to be carried out on an annual basis; some may be implemented at longer regular intervals. This applies especially to aspects of data collection that do not change from year to year. Requirements pertaining to the frequency and completeness of QC measures are more stringent for key categories than for other categories. It should be ensured that all categories undergo detailed quality control at least periodically.

22.1.2.1.6 Category-specific quality control

Available resources permitting, particularly relevant categories (such as key categories), in addition to undergoing Tier 1 procedures, should undergo Tier 2 quality control with regard to determination of activity rates, emissions and uncertainties (cf. Chapter 8.7 *Good Practice Guidance*). The chapters of the IPCC Good Practice Guidance that pertain to the various individual categories (Chapter 5) include additional information relative to category-specific QC measures. Such guidelines must be observed in preparation of any QC/QA plan: :

Where combined **activity data** from secondary sources are used, good practice calls for evaluating pertinent QC measures in connection with preparation of such secondary sources. If the level of such measures is adequate, it suffices to call attention to this fact in the documentation. Where secondary sources do not fulfill minimum requirements pertaining to quality control, suitable QC/QA checks should be carried out by the institution that uses the data. Results of subsequent QC/QA checks should enter into determination of uncertainties for activity rates. In addition, wherever possible, a range of different sources should be compared for purposes of determining data quality.

In use of facility-specific activity data, it is good practice to review the methods and QC/QA standards applied to data collection. Where such methods and standards do not meet minimum requirements, the advisability of using the data should be reconsidered and the uncertainties should be adjusted as necessary.

With regard to **emissions data**, it is good practice to review the emission factors that have been used. Such efforts include using national emission factors for key categories and reviewing the validity of IPCC standard factors under the applicable national circumstances. Where emissions data are obtained via direct measurements, it is good practice to review the relevant measurement methods and the quality standards applied. Emissions data and emission factors should be reviewed in light of data from previous years, and from independent sources, and any resulting discrepancies should be explained.

Quality control for uncertainties includes checking to determine whether calculations are free of errors and whether documentation for reproduction of results is adequate. In use of experts' assessments, the pertinent experts' qualifications and estimation methods should be reviewed and documented.

22.1.2.1.7 Quality assurance procedures

While the primary aim of quality control is to ensure that methods are correctly applied, the primary purpose of quality assurance is to examine methods as such and improve them as necessary.

Pursuant to the relevant IPCC definition (Chapter 8.1 Good Practice Guidance), measures for **quality assurance** (QA) are based *"on a planned system of reviews by persons who are not directly involved in preparing the inventory. Such reviews – which are best carried out by independent third parties – should be applied to completed inventories, after QC procedures have been carried out. Such measures accomplish the following:*

- Verify that data-quality criteria are fulfilled,
- Ensure that the inventory takes account of the best available estimates of emissions and sinks, in keeping with the latest scientific findings and available data, and
- Promote the efficiency of the QC system".

The required instrument for quality assurance is the peer review. While use of audits is encouraged, audits are not required.

22.1.2.1.8 Reporting procedures

The Single National Entity is responsible for initiating and co-ordinating reporting and carrying out relevant overall organisation. Provision of data and reports by third parties must conform to applicable requirements pertaining to the scope, form and scheduling of/for such provision.

22.1.2.1.9 Documentation and archiving

As a general requirement, all data and information used for inventory calculation must be documented (i.e. recorded) and archived, for each report year. The purpose of such documentation (i.e. recording) is to make it possible to completely reconstruct all emissions calculations after the fact. The general requirements pertaining to documentation and archiving for the entire process of preparation of greenhouse-gas inventories are described in Chapter 8.10.1 of the *IPCC Good Practice Guidance*.

Consequently, data providers have the obligation to keep records of the following information relative to data they supply to the Federal Environment Agency, for purposes of inventory calculations:

Data providers:

- Publication / source of activity data, with detailed referencing of the relevant Table numbers and names, and of the relevant pages in the original sources;
- Survey contents (definitions of the surveyed characteristics, delimitations used, survey units used) and survey methods;
- The legal foundations and ordinances on which surveys are based;
- Chronological and spatial comparability with previous-year data, and any changes with regard to definitions, scopes of validity, cut-off points, sources of activity rates or data-collection methods;
- Any revision of previously published data;
- The accuracy or quantitative error of activity data, methods used to estimate errors and the names of experts who have carried out error estimation.

- Secrecy and data protection: suitable notification with regard to any individual data items that are considered secret.

Such materials should be provided to the Federal Environment Agency on an annual basis, together with pertinent data, and they are centrally archived by the Federal Environment Agency.

Quality control (QC)

The records kept in the framework of quality control should include the names of the persons responsible for managing and carrying out relevant actions, the types of quality control carried out, the dates on which quality control measures were carried out, the pertinent results, and the corrections and modifications triggered by quality control measures. In each case, record-keeping and archiving for quality control measures are carried out internally, by the institution supplying the pertinent data. A general description of regularly executed quality control measures is provided to the Federal Environment Agency for purposes of the national inventory report and inventory review.

Providers of emissions calculations

For providers of emissions calculations, the minimum requirements pertaining to record-keeping also include the following:

- Description of the pertinent calculation methods and reasons why the methods were selected;
- Assumptions and criteria pertaining to selection of activity data and emission factors;
- Documentation pertaining to emission factors and their sources, with detailed references to the relevant numbers and pages in original sources;
- Calculation models;
- Calculation files, calculation software.

Points 1-4 are recorded and archieved along with descriptions provided for the national inventory report. Separate documentation pertaining to calculation models must be provided, in keeping with general scientific practice, and along with internal documentation in the form of manuals or guides. Data suppliers archive calculation files and calculation software, and keep pertinent records, on an internal basis. Such materials should be provided to the Federal Environment Agency as necessary in the framework of inventory review.

Quality assurance

In addition to carrying out quality control measures, providers of emissions calculations are obligated to carry out quality assurance. The records kept in the framework of quality assurance should include the names of the persons responsible for managing and carrying out relevant actions, the types of quality assurance carried out, the dates on which quality assurance measures were carried out, the pertinent results, and the corrections and modifications triggered by quality assurance measures. In addition, records should be kept of category-specific quality controls.

In each case, record-keeping and archiving relative to pertinent quality assurance are carried out internally, by the relevant data-supplying institution. In addition, pertinent quality assurance measures are summarised in the national inventory report.

Confidential data / secrecy

In general, confidential data must be designated as such when they are provided, to ensure that the proper precautions are taken when they are used.

In inventory review, general obligations apply whereby confidential data must be disclosed in cases in which inventory reviewers consider such disclosure to be necessary to ensure that emissions calculations are transparent and clear. The extent to which such disclosure actually must involve disclosure of individual data items should be clarified on a case-by-case basis with the institution providing the data.

22.1.2.1.10 Annex 1: Minimum requirements pertaining to quality control and quality assurance in emissions reporting in the Federal Environment Agency

22.1.2.1.10.1 Introduction

The general minimum requirements, as approved by the co-ordinating committee for the National System of Emissions Inventories, pertaining to quality control and quality assurance (QC/QA) in reporting on greenhouse-gas emissions apply to all participants. These requirements are the basis for collecting, processing, forwarding and reporting of/on all data that support reporting on greenhouse-gas emissions. They are thus binding for all working groups involved, in the Federal Environment Agency, in fulfillment of this reporting task.

22.1.2.1.10.2 System for quality control and quality assurance

In addition to the general minimum requirements, approved by the co-ordinating committee for the National System of Emissions Inventories, pertaining to quality control and quality assurance (QC/QA) in reporting on greenhouse-gas emissions, the specific provisions of in-house directive (Hausanordnung) No. 11/2005 also apply at the Federal Environment Agency. Pursuant to that directive, the pertinent procedure defined in the QSE manual is binding for all Federal Environment Agency personnel involved in emissions reporting (Rules of procedure of the Federal Environment Agency (Geschäftsordnung des Umweltbundesamtes), Volume II, Numeral XV).

The in-house directive fully implements the requirements of Chapter 8 of the *IPCC Good Practice Guidance*. Suitable UBA-specific instruments have been established to ensure effective identification and execution of measures for continual inventory improvement (improvement plan and inventory plan; cf. 22.1.2.1.10.3). That work has led to the development of the Quality System for Emissions Inventories (QSE), via which the points mentioned in Chapter 22.1.2.1.2 have been implemented.

22.1.2.1.10.2.1 Agency responsible for co-ordinating QC/QA activities in the Federal Environment Agency

Pursuant to in-house directive No. 11/2005, section FG I 2.6, "Emissions Situation", is the "Single National Entity" (SNE) within the Federal Environment Agency. In the Federal Environment Agency's organisational diagramme, the so-defined SNE is thus included in the Federal Environment Agency’s group of "focal points" and liaison offices for international organisations. In addition, this assignment of responsibility was confirmed by the relevant ministries via a state secretaries' resolution of 5 June 2007.

The roles and responsibilities of the Single National Entity, and of the specialised departments participating in emissions reporting, are described in Chapter 3.2, "Roles and responsibilities", of the QSE manual. The Single National Entity is responsible for updating and managing the QSE manual and its appendices and annexes. In carrying out this responsibility, the SNE is assisted by the contact persons named to it by the relevant specialised departments. The version of the QSE manual and its co-applicable documents published on the Single National Entity's intranet is the binding version of these materials.

22.1.2.1.10.2.2 Reporting procedures

In many cases, complex activities comprise numerous different, but related and cumulative, activities (processes) that lead to the production of a single product. To manage such processes effectively, one must strive to understand the manner in which the processes function (or should function), to describe such functioning in logical, realistic ways (activities, dependencies, responsibilities, and many more) and to interrelate the processes in a useful way.

In practice, workflows of complex processes cannot always be fit smoothly into the hierarchical, traditional structures of companies and institutions. The required processes are often diametrally opposed to such structures, since they have to cut across different organisational units. To organise interrelated work processes in a manner oriented to production of the desired product, one must look outside of rigid hierarchies and redefine the processes with a view to improvement.

For this reason, emissions reporting was first described as a process that, via a number of interrelated activities, leads to a product (NIR and inventories) (cf. Figure 88). Additional relevant information is provided in the QSE manual, Chapter 4.3.

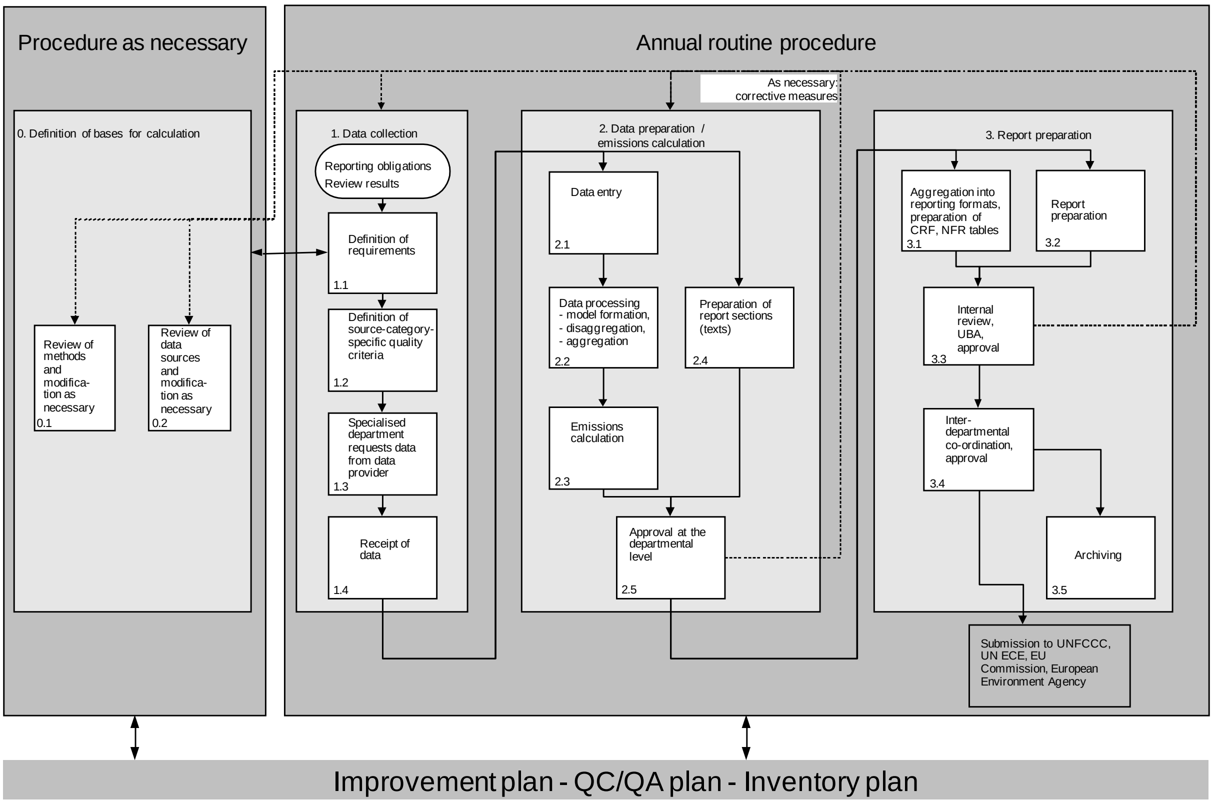

Figure 88: Overview of the overall emissions-reporting process

Via a role concept, suitable responsibilities have been assigned to cover the activities within the main processes and sub-processes shown. Each responsibility thus involves execution of pertinent processes. To understand this approach, it is useful to consider the situation in which many different people carry out the same basic activities even though they work in different work units and categories. In the present case, this situation was approached by defining a certain group of persons (persons with a specific role – for example, responsible experts). That group was then seen to be subordinate to another group of persons (with a different role – for example, specialised contact persons) that ensures that the first group observes and fulfills the requirements pertaining to its work. In addition, a QSE co-ordinator was appointed, in keeping with relevant requirements of the IPCC (cf. Chapter 22.1.2.1.2), to ensure that the system is refined and improved as necessary.

Overall, a comprehensive role concept was developed that addresses the many different requirements applying to the Federal Environment Agency in its task as Single National Entity. The roles involved include the following:

1. **Responsible expert at the operational level (FV)**
   - Main responsibilities: data collection, data entry, calculations with prescribed methods, execution of QC measures, preparation of the NIR text

2. **Quality control manager (QKV)**
   - Is the superior for the FV
   - Main responsibilities: checking and approving data and report sections

3. **Specialised contact person (FAP)**
   - Member of the Single National Entity's staff
   - Main responsibilities: providing category-specific support for involved experts (inventory work and report preparation) and quality control / quality assurance relative to pertinent categories in the NIR and CSE.

4. **Co-ordinator for the national inventory report (NIRK)**
   - Member of the Single National Entity's staff
   - Main responsibilities: co-ordination of supporting textual work, preparation of the NIR from the various relevant contributions, overarching QC and QA for the NIR

5. **CSE co-ordinator (ZSEK)**
   - Member of the Single National Entity's staff
   - Main responsibilities: maintenance of databases, emissions calculation and aggregation, overarching QC and QA in connection with data entries and calculations for the inventory

6. **QSE co-ordinator (QSEK)**
   - Member of the Single National Entity's staff
   - Main responsibilities: maintenance and refinement of the QSE (system, checklists, improvement plan, inventory plan, QC/QA plan and QSE manual)

7. NaSE co-ordinator (NaSEK)

- Member of the Single National Entity's staff
- Main responsibilities: schedule-conformal, requirements-conformal reporting, providing for involvement of national institutions, establishing/recording legal agreements

As a rule, each of the above-described roles will have tasks in several different main and sub-processes of emissions reporting.

22.1.2.1.10.3 QC plan, QA plan and inventory plan

To ensure that all potential improvements identified during the course of inventory work are systematically implemented, identified improvements must be listed in a co-ordinated way. In the process, identified potential improvements should be listed together with all relevant information (origin of the potential improvement, source category, pertinent responsibility, priority, etc.) needed for efficient further processing. Planning and arrangements for implementing identified potential improvements (required actions / corrective measures, deadlines, etc.) should then be made on the basis of such information.

In the interest of proper control and record-keeping in the framework of the NaSE and the QSE (cf. Figure 89), procedures have been defined for processing identified potential improvements for their systematic management and further use. The overall aim is to answer the central question of WHO should do WHAT, HOW, WHEN and WHY:

WHO: This provides the reference to the role concept: A certain person xy is responsible – for example, in the role of responsible expert (FV)

WHAT: This provides the reference to the object that is to be improved – for example, the CO_2 calculation in category xy needs to be improved

HOW: This provides the reference to the aim that is to be achieved – for example, a certain improvement, pursuant to an inventory plan or checklist.

WHEN: This provides the reference to the time by which the improvement must be completed, pursuant to the inventory plan

WHY: This provides the reference to the origin of the necessary action – for example, the improvement must be carried out as a result of a recommendation via the UNFCCC review process

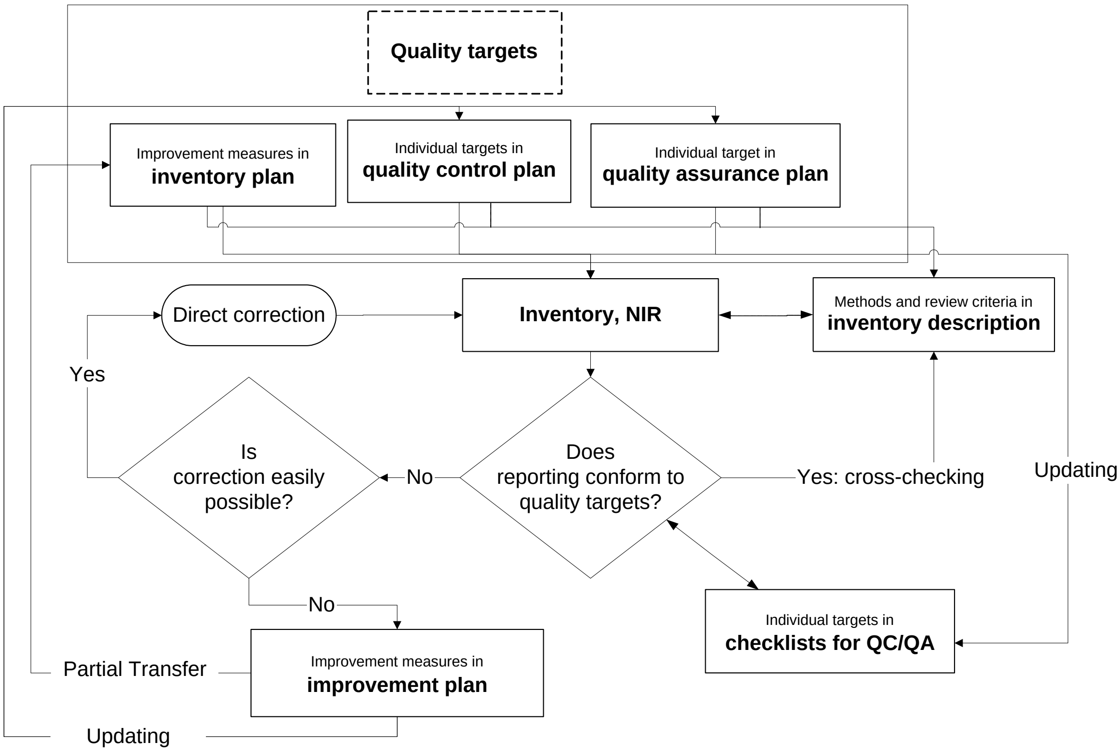

Figure 89: Control and documentation in the framework of the NaSE and the QSE

The **quality targets** have been derived from the general quality aims of the IPCC Good Practice Guidance (transparency, consistency, accuracy, comparability, completeness). In addition, operational individual objectives, relative to quality control and quality assurance, for the various categories, have to be derived from comparison of the requirements from the *IPCC Good Practice Guidance*, the results of independent inventory review (UNFCCC and EU) and assessment of inventory realities.

In an **improvement plan**, all potential improvements and criticisms resulting from independent inventory review are collected and assigned potential corrective measures. The Single National Entity categorises the corrective measures, prioritises them and then, via consultations with the relevant responsible experts, integrates them as necessary within the **inventory plan**. There, they are linked with deadlines and responsibilities. As an annex to the NIR, the inventory plan undergoes a co-ordination and release process in the Federal Environment Agency and in the co-ordinating committee. It is thus a binding set of specifications for improvements to be carried out in future.

In the interest of transparent, effective control and execution of inventory-improvement measures, such measures, in keeping with the *IPCC Good Practice Guidance* (Chapter 8.5) are defined role-specifically, as well as category-specifically as necessary, in the **quality control plan / quality assurance plan (QC/QA plan)**. The QC plan is oriented solely to quality control aims for the inventory. In the QA plan, quality assurance objectives may be focused on the inventory, the reporting process or the QSE itself. Furthermore, the quality assurance plan includes scheduling of quality assurance measures to be performed by external third parties.

The **checklists for quality control and quality assurance** list all individual objectives in the emissions-reporting process, in keeping with the pertinent quality control and quality assurance plans. The checklists, which are designed to facilitate review of achievement of individual objectives, are made available to all persons responsible for quality control and quality assurance. The checklists are used to record execution of measures for quality control and quality assurance. Where individual objectives are not achieved and direct correction is not possible, a pertinent entry must be made in the improvement plan (see above).

22.1.2.1.10.4 Procedures for general and category-specific quality control

From the requirements set forth in the IPCC Good Practice Guidance, the Federal Environment Agency has developed a checklist concept via which quality requirements are formulated as specific targets. Every effort should be made to achieve such targets. When a target is achieved, such achievement is noted and described in the checklists. The possible entries for such records include "yes" (the target was achieved), "not relevant" (the target as formulated does not correspond to the special situation for the source category in question; this answer is seldom a viable option) and "no" (it was not possible to achieve the target).

Each checklist includes a general section that reflects all Tier 1 QC requirements from IPCC Good Practice Guidance and that is used in connection with every instance of reporting. In addition, each checklist contains a category-specific section (Tier 2) that provides concrete objectives for the relevant key category area.

Checklists are provided only for the first five roles within the role concept. Where different roles are responsible for different main and sub- processes of emissions reporting (cf. Chapter 22.1.2.1.10.2.2), pertinent checklists will also be oriented to several different main and sub-processes of emissions reporting. They thus represent a cross-section of emissions reporting. The checklists of the FV and the FAP include a basic common set of goals. The FAP are responsible for checking the work of the FV, and such checking is most effective when both roles are oriented to the same goals.

22.1.2.1.10.5 Quality assurance procedures

In the role concept, procedures are designed to ensure that quality assurance is always supported by a "four-eyes" principle. The specialised contact persons (FAP) have the task of ensuring that the emissions calculations and textual work of the responsible experts (FV) are of the proper quality.

In its section on "Expert Peer Review", the IPCC notes that the (above-described) formal procedure selected by the Federal Environment Agency can complement, but not replace, expert peer review (Good Practice Guidance; Chapter 8.8). In one solution found for addressing the justified call for inclusion of external experts, within the framework of available resources, detailed review of specific issues is carried out by external third parties via research projects and studies. In general, the two sides involved (i.e. FV and FAP) jointly manage the process of commissioning third parties. In another means found for addressing the need for third-party inclusion, workshops on the National System are held at irregular intervals. For such workshops, national experts are invited to come to the Federal Environment Agency for discussion with Federal Environment Agency experts (FV) on current inventory issues relative to selected categories.

No audits have been carried out in the Federal Environment Agency to date, and none are planned at present. According to the Good Practice Guidance, audits are not absolutely required.

22.1.2.1.10.6 Documentation and archiving

Standardised record-keeping and archiving procedures are to be used in preparation of German greenhouse-gas inventories. At the same time, it is important to differentiate between the central record-keeping and archiving carried out by the Single National Entity and the non-central record-keeping and archiving carried out by the specialised departments of the Federal Environment Agency and of other institutions.

Record-keeping procedures for data and context information vary in accordance with specific requirements. In their information storage, they overlap to some degree, with such overlapping consisting partly of redundancies and partly of storage of similar items at differing levels of detail. On a regular basis, consistency must be ensured for both types of overlapping.

To ensure that all of the Federal Environment Agency's working units use basically consistent procedures, the specifications applying to the instruments used in such procedures – including both general specifications and specifications developed especially for emissions reporting – must be complied with. For purposes of "documentation" (i.e. record-keeping), the Federal Environment Agency has access to the instruments described in Table 432. The specifications pertaining to each type of document / record must be observed. Where no special specifications apply, the provisions from the "General minimum requirements for quality control and quality assurance in reporting on greenhouse-gas emissions" ("Allgemeine Mindestanforderungen an die Qualitätskontrolle und Qualitätssicherung bei der Treibhausgasemissionsberichterstattung") apply.

Table 432: Documentation / record-keeping instruments at the Federal Environment Agency

Instrument	Specifications
Publicly available	
National inventory (CRF tables, CRF-Reporter)	Annex 2, QSE manual: instructions for carrying out recalculations in the CRF tables
National Inventory Report	Annex 3, QSE manual: specifications for preparing report sections in the context of the National System
Publication	Rules of procedure of the Federal Environment Agency: Point 6.2 Publications
Published manuals, guides	For IT descriptions: procedural model of the Federal Environment Agency; otherwise: no special specifications
Centralised, and internally available, at the Single National Entity	
CSE database	Annex 5, QSE manual: specifications for data recording within the CSE
Inventory description	Annex 4, QSE manual: requirements pertaining to documentation (record-keeping) and archiving
De-centralised, and internally available	
Files of the central registry	Rules of procedure of the Federal Environment Agency: Point 4.2.10 Handling of files
Reference files	no special specifications
Internal manuals, guides	For IT descriptions: procedural model of the Federal Environment Agency; otherwise: no special specifications

An integrated documentation / record-keeping concept defines what key content should be stored in the aforementioned documentation instruments. It also defines how a suitable referencing system is to be used to ensure consistency and transparency throughout all such instruments (cf. Annex 4, QSE manual).

22.1.2.1.11 Annex 2: Example of a general checklist for the responsible-expert role

The example presented below (last revision: CHKL 2010) includes only the relevant requirements. Detailed information has been removed in the interest of clarity.

Table 433: General checklist for responsible experts

Process No.	Sub-process name	Individual goal	Optional goal
Main process: 0. Definition of bases for calculation			
0.1	Review of methods, and modification as necessary	The calculation method is in conformance with current key-category analysis.	
0.1	Review of methods, and modification as necessary	The calculation method has been selected in accordance with, or accords with, the pertinent decision tree of the IPCC Good Practice Guidance.	Departures from the decision tree of the IPCC Good Practice Guidance have been properly explained, in keeping with logical and pertinent specialised criteria, and have been duly documented.
0.1	Review of methods, and modification as necessary	The calculation method has been selected in keeping with requirements from the inventory plan.	Departures from the inventory plan have been properly explained, in keeping with logical and pertinent specialised criteria, and have been duly documented.
0.1	Review of methods, and modification as necessary	The selected calculation method can be applied to the entire time series as of 1990, or is already being consistently applied.	In cases of changes of methods in the time series, recalculation pursuant to the QSE manual (Annex 2), and proper pertinent documentation, are assured.
0.1	Review of methods, and modification as necessary	Departures from the objectives required via 0.1.01-0.1.04 have been properly explained, in keeping with logical and pertinent specialised criteria, and have been duly documented.	
0.2	Review of data sources, and modification as necessary	Have new data sources been used?	
0.2	Review of data sources, and modification as necessary	The data source(s) is / are / will be available throughout the long term (for example, on the basis of legal provisions, long-term agreements [> 3 years], etc.).	
0.2	Review of data sources, and modification as necessary	One / several complete time series as of 1990 are available in the data source(s).	Gaps in the data available for time series as of 1990 have been properly and logically explained, and have been duly documented.
0.2	Review of data sources, and modification as necessary	One / several complete time series as of 1990 are available in the data source(s).	A suitable procedure (interpolation/ extrapolation) has been chosen for dealing with data gaps, in conformance with IPCC Good Practice Guidance (Chap. 7.3.2.2), and the procedure has been logically documented. Note: Continued use of the same value is not extrapolation !
0.2	Review of data sources, and modification as necessary	One / several complete time series as of 1990 are available in the data source(s).	Following closure of data gaps, time-series recalculation has been carried out as necessary, pursuant to QSE manual (Annex 2), and such recalculation has been documented and substantiated in the NIR and CRF.

Process No.	Sub-process name	Individual goal	Optional goal
0.2	Review of data sources, and modification as necessary	The data source(s) completely cover the category.	The incomplete coverage has been addressed in an extrapolation and has been taken into account in the uncertainties calculation. All steps have

			been documented and justified clearly and logically.
0.2	Review of data sources, and modification as necessary	Uncertainties information (amount and distribution) is available for the data source(s).	
0.2	Review of data sources, and modification as necessary	The EF and the AD agree in terms of the manner in which they are tailored to the source category.	In the case of discrepancies between the EF and AD, other data sources can establish agreement between the two values. Alternatively, the lack of agreement has been taken into account in an extrapolation, and in the uncertainties calculation, and the entire process has been properly and logically documented.
0.2	Review of data sources, and modification as necessary	The procedures for calculating outset data are clearly described.	
0.2	Review of data sources, and modification as necessary	The data source(s) have been selected in keeping with requirements from the inventory plan.	Any discrepancies have been clearly and logically justified and documented.
0.2	Review of data sources, and modification as necessary	The assumptions and criteria upon which the relevant data source(s) have been selected have been clearly and logically documented.	
0.2	Review of data sources, and modification as necessary	The data provider has carried out routine quality controls of the data source(s). For one-time projects, one-time quality controls have been carried out. Execution of the controls has been duly documented.	
0.2	Review of data sources, and modification as necessary	In use of one/more new data sources, a recalculation pursuant to the QSE manual (Annex 2) was carried out on the basis of this/these other data source(s).	
0.2	Review of data sources, and modification as necessary	In use of IPCC default EF, the manner in which the EF were generated has been reviewed in light of national circumstances, and the EF may be used for Germany. The result of such review has been duly documented.	For IPCC default values that do not fit with national circumstances, the discrepancies have been taken into account in the uncertainties and documented.
0.2	Review of data sources, and modification as necessary	In use of EF other than the IPCC default EF, use of such EF has been clearly and logically justified and substantiated. Note: Use of other EF is permissible only when such EF permit more precise calculation of country-specific emissions.	
0.2	Review of data sources, and modification as necessary	The AD used have been compared with other data sources (for example, EU-ETS, IEA, EPER, etc.), and the result has been duly documented.	

Main process: 1. Data collection

1.1	Definition of requirements	The requirements pertaining to data reflect the information and indications from the inventory plan and the inventory reviews (for example, S&A Report, Centralized Review).	

Process No.	Sub-process name	Individual goal	Optional goal
1.3	The relevant specialised department requests the data from the pertinent data provider(s)	The requirements pertaining to QC and data formats have been forwarded to the data suppliers and/or contracting entities, and such forwarding has been duly documented. Note: Where data suppliers are involved via NaSE agreements, this objective has been achieved.	The data supplier (for example, an association) carries out its own routine quality controls, and the results have been duly documented.

1.4	Receipt of data	The data provider or contracting entity has carried out the required quality controls and made proper records of such action.	The data supplier (for example, an association) carries out its own routine quality controls, and the results have been duly documented.
1.4	Receipt of data	The received data are complete, without any gaps.	All data gaps in the time series as of 1990 have been closed, in accordance with the IPCC Good Practice Guidance, via extrapolation/interpolation (Chapter 7.3.2.2) and duly documented and justified. Note: Continued use of the same value is not extrapolation
1.4	Receipt of data	The data received are consistent with the previous year's data, and they have been properly described.	Any marked discrepancies with the previous year's data have been duly documented and justified.
1.4	Receipt of data	The order of magnitude of the received data is in line with that of comparable data from other sources (such as ETS data, IEA, EPER, etc.). The result of the review has been duly documented.	The reasons for any discrepancies have been clearly and logically explained and duly documented.
1.4	Receipt of data	The methods/assumptions on which the uncertainties determinations are based have been clearly and logically documented.	Where it was not possible to derive assumptions, expert assessment was carried out, and the relevant expert's quantification was clearly and logically documented.
1.4	Receipt of data	The uncertainties determinations are complete and plausible.	
Main process: 2. Data preparation / emissions calculation			
2.1	Data entry (preferably into the CSE)	All of the EF have been entered into the CSE.	
2.1	Data entry (preferably into the CSE)	The documentation for the EF data source(s) is complete and conforms to the requirements of the QSE manual (Annexes 3, 4 and 5).	
2.1	Data entry (preferably into the CSE)	Development of the EF within the time series has been plausibly explained and, in the case of unusual effects (such as changes in order of magnitude), has been clearly and logically explained and documented.	Implausible EF have been corrected.
2.1	Data entry (preferably into the CSE)	All of the AD have been entered into the CSE.	
2.1	Data entry (preferably into the CSE)	The documentation for the AD data source(s) is complete and conforms to the requirements of the QSE manual (Annexes 3, 4 and 5).	

Process No.	Sub-process name	Individual goal	Optional goal
2.1	Data entry (preferably into the CSE)	Development of the AD within the time series has been plausibly explained and, in the case of unusual effects (such as changes in order of magnitude), has been clearly and logically explained and documented.	Implausible discrepancies have been corrected.
2.1	Data entry (preferably into the CSE)	Following entry of all data into the CSE, all entered figures, units and conversion factors have been checked for correctness and confirmed.	
2.1	Data entry (preferably into the CSE)	All of the uncertainties have been entered into the CSE and have been documented in keeping with the requirements of the QSE manual (Annexes 3, 4 and 5).	

2.2	Data preparation (model formation, disaggregation, aggregation)	The inventory description includes an adequate description of pertinent models, with regard to organisation, structure, calculation procedures, assumptions, etc..	
2.3	Emissions calculation	The current inventory calculations have been checked against calculations from previous reports.	Where any significant changes or obvious deviations from an expected trend have occurred, the pertinent calculation, and the data used in calculation, have been reviewed, and any persisting discrepancies have been properly, clearly and logically explained and duly documented.
2.3	Emissions calculation	The results of emissions calculation for current / previous reports have been checked against other data sources for Germany, especially ETS data, and found to be comparable. The result has been duly documented.	Where comparability has not been found, or no comparison was carried out, the pertinent reasons have been properly, clearly and logically explained.
2.3	Emissions calculation	The national Implied EF (cf. S&A Report I) from the previous report is comparable with the Implied EF of other countries (same order of magnitude).	Extreme Implied EF have been properly, clearly and logically explained, and duly documented, in the NIR, or reference to an existing explanation has been made.
2.4	Preparation of report sections (texts)	The category has been completely and logically described, for the NIR, in terms of the required six sub-chapters for the NIR ("Category description", "Methodological issues", etc.).	
2.5	Approval by the relevant experts	The values of AD, EF and ED, of their uncertainties, are up to date in the NIR and congruent with the pertinent values in the CSE.	
2.5	Approval by the relevant experts	Documentation of the origins for AD, EF and ED data, and for their uncertainties, are up to date in the NIR and congruent with the pertinent values in the CSE.	Lacking or incomplete documentation of data origin has been properly, clearly and logically explained and duly documented.

22.1.3 The database system for emissions – Central System of Emissions

Since 1998, the Federal Environment Agency has maintained and managed an IT tool for inventory preparation: the *Central System of Emissions (CSE)*, an integrated national database. The CSE implements the diverse requirements pertaining to emissions calculation and reporting, and it automates key steps in such work. It supports the processes of inventory planning and reporting (for example, by carrying out emissions calculations and recalculations, and relevant error analysis); inventory management (for example, by carrying out archiving and annual data evaluation); and quality management at the data level (cf. UBA 2003a, Projekthandbuch Decor (Decor project handbook)). The CSE makes it possible to fulfill the key requirements of transparency, consistency, completeness, comparability and accuracy at the data level.

Data documentation plays a central role in the CSE. The CSE stores such information as who is responsible for handling specific tasks; data sources and calculation procedures; and uncertainties in time-series values. The times at which changes are made, and the persons by whom they are made, are also recorded. The system has a history-management function that archives deleted items and can restore them as necessary. This makes it possible to trace back and reconstruct data, and it enables third parties to carry out independent reviews. The system also provides mechanisms that support quality assurance at the data level (e.g. components for detecting uncertainties and checking plausibility). Above all, transparency is accommodated by ensuring that data are recorded within the same structure in which they are provided, and that all processing and transformations into a reporting format take place first in the CSE itself, and thus remain open to examination. In addition, the CSE manages detailed technology-specific activity data and emission factors that can be processed, via calculation rules (calculation methods), into aggregated, category-specific values for the various reporting formats. Aggregation of individual CSE time series for the CRF report lines, for example, is described in Annex 3 and Chapter 3ff – in each case, with regard to individual categories. In addition to aggregation and model formation for calculations, the CSE also supports scenario and forecast calculations and use of the reference approach.

Data exchange within the framework of the National System – i.e. within the Federal Environment Agency and with third parties – is also organised via the Central System of Emissions. Such processes involve both direct data entry and imports of aggregated values, from existing databases and via a standard interface (for example, TREMOD, for transport data; and GAS-EM, for agricultural data). Ideally, inventory data should be entered into the CSE directly by the relevant responsible experts or should be imported, by the CSE administrator, via the import interface. This applies to in-house UBA employees as well as to external parties involved in the National System. To this end, a range of measures have been implemented:

- Provision of a *standardised import format for the CSE* in 2002 has facilitated the direct import of data from other emissions-relevant databases.
- In September 2002, participating technical experts from the Federal Environment Agency were given direct access to the CSE via the Federal Environment Agency intranet.
- Since November 2002, training courses on CSE procedures have been held on an annual basis for involved Federal Environment Agency staff.
- Since 2005, qualitative and quantitative information about data uncertainties has also been included in the CSE.
- Since 2006, reporting obligations under the Geneva Convention on Long-Range Transboundary Air Pollution and EU legislation (such as the NEC directive) have been fulfilled via the CSE.
- Since 2008, data providers and experts outside of the Federal Environment Agency, and project partners, can work interactively with the CSE via remote access.

22.2 Supplementary information as required pursuant to Article 7 (1) of the Kyoto Protocol

22.2.1 KP-LULUCF

The CRF tables are reported separately.

22.2.2 Standard Electronic Format (SEF) Tabellen

22.2.3 More-detailed information about the National System, and about changes within the National System

All of this information has been provided in the preceding chapters.

22.2.4 Further detailed information about the National Registries and accounting of Kyoto units

22.3 Additional information about greenhouse-gas trends

Here, we provide the detailed tables relative to the trend discussion presented in Chapters 0.2 and 0.

Table 434: Emissions trends in Germany, by greenhouse gas and source category

GHG emissions / sinks, in CO_2 equivalents (Gg)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Net CO_2 emissions / removals	1,016,520	980,921	932,095	922,883	903,592	902,060	922,294	892,956	884,702	856,401	858,304	873,773	892,759	892,127	874,592
CO_2 emissions (not including LULUCF)	1,050,885	1,012,909	964,648	955,113	938,939	938,024	958,363	930,802	922,815	895,425	899,386	915,682	899,265	900,522	885,910
CH_4	119,742	114,174	110,748	111,296	107,464	105,288	102,692	98,491	93,355	92,831	89,952	86,277	82,379	78,948	73,917
N_2O	65,825	63,401	64,391	61,600	62,389	61,723	62,965	60,096	47,193	43,744	43,729	45,101	44,279	43,910	46,035
HFC	5,754	5,278	5,501	7,695	8,156	8,354	7,694	8,324	8,935	9,100	8,020	9,109	9,780	9,087	9,375
PFC	3,060	2,655	2,407	2,256	1,919	2,086	2,041	1,653	1,782	1,485	956	870	946	1,016	977
SF_6	4,428	4,746	5,238	5,974	6,249	6,467	6,162	6,109	5,889	4,290	4,072	3,752	3,087	3,034	3,244
NF_3	7	7	7	7	7	5	7	8	8	7	9	8	12	19	23
Total emissions / removals, including LULUCF	*1,215,336*	*1,171,182*	*1,120,386*	*1,111,712*	*1,089,775*	*1,085,983*	*1,103,856*	*1,067,636*	*1,041,863*	*1,007,858*	*1,005,043*	*1,018,889*	*1,033,242*	*1,028,141*	*1,008,163*
Total emissions, not including CO_2 from LULUCF	1,249,701	1,203,170	1,152,939	1,143,942	1,125,122	1,121,948	1,139,925	1,105,483	1,079,976	1,046,882	1,046,125	1,060,798	1,039,747	1,036,536	1,019,480

GHG emissions / sinks, in CO_2 equivalents (Gg)	2005	2006	2007	2008	2009	2010	2011	2012	2013
Net CO_2 emissions / removals	852,040	863,457	836,766	832,524	768,407	813,702	793,809	800,397	823,125
CO_2 emissions (not including LULUCF)	865,931	877,971	850,861	854,061	789,107	833,112	812,665	817,913	840,605
CH_4	70,682	66,717	64,247	63,438	61,215	60,352	59,279	60,082	59,475
N_2O	44,001	43,735	45,623	46,080	45,271	37,247	38,543	37,728	38,104
HFC	9,581	9,784	9,885	10,081	10,660	10,242	10,485	10,710	10,742
PFC	837	668	586	565	405	344	277	241	257
SF_6	3,320	3,242	3,181	2,971	2,924	3,047	3,163	3,155	3,261
NF_3	34	28	12	30	29	61	61	35	17
Total emissions / removals, including LULUCF	*980,495*	*987,631*	*960,301*	*955,688*	*888,910*	*924,996*	*905,616*	*912,348*	*934,980*
Total emissions, not including CO_2 from LULUCF	994,386	1,002,144	974,395	977,226	909,609	944,406	924,472	929,864	952,460

GHG emissions / sinks, by source and sink categories, in CO_2 equivalents (Gg)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1. Energy	1,037,165	1,000,479	951,867	942,839	920,509	918,693	939,848	908,886	899,262	874,951	873,037	893,044	876,716	872,079	854,524
2. Industrial processes	96,404	92,517	92,552	93,588	99,181	97,366	95,587	95,853	82,052	74,013	76,950	73,663	72,353	76,181	78,147
3. Agriculture	77,889	70,571	68,332	67,521	66,240	67,653	67,628	66,717	66,683	67,473	67,160	66,708	64,606	63,677	63,612
4. Land use, land-use changes & forestry	-32,531	-30,165	-30,707	-30,415	-33,541	-34,168	-34,273	-36,062	-36,336	-37,253	-39,316	-40,160	-4,772	-6,666	-9,611
CO_2	*-34,365*	*-31,988*	*-32,552*	*-32,230*	*-35,347*	*-35,965*	*-36,069*	*-37,846*	*-38,113*	*-39,024*	*-41,082*	*-41,909*	*-6,506*	*-8,396*	*-11,318*
N_2O & CH_4	*1,834*	*1,823*	*1,846*	*1,815*	*1,806*	*1,797*	*1,797*	*1,785*	*1,777*	*1,771*	*1,767*	*1,748*	*1,734*	*1,730*	*1,707*
5. Waste	36,409	37,780	38,342	38,179	37,385	36,439	35,066	32,242	30,202	28,674	27,211	25,634	24,339	22,870	21,490

GHG emissions / sinks, by source and sink categories, in CO_2 equivalents (Gg)	2005	2006	2007	2008	2009	2010	2011	2012	2013
1. Energy	834,623	844,150	817,163	822,663	764,675	804,208	782,862	790,281	813,439
2. Industrial processes	74,929	75,672	76,754	72,962	65,200	62,381	62,943	62,067	61,372
3. Agriculture	63,046	62,121	61,506	63,802	63,100	62,260	63,847	63,398	64,243
4. Land use, land-use changes & forestry	-12,199	-12,809	-12,383	-19,814	-18,962	-17,662	-17,098	-15,745	-15,694
CO_2	*-13,891*	*-14,513*	*-14,094*	*-21,538*	*-20,699*	*-19,410*	*-18,856*	*-17,516*	*-17,481*
N_2O & CH_4	*1,693*	*1,704*	*1,711*	*1,723*	*1,737*	*1,748*	*1,758*	*1,771*	*1,787*
5. Waste	20,096	18,496	17,260	16,076	14,897	13,809	13,062	12,347	11,620

Table 435: Contributions to emissions trends in Germany, by greenhouse gas and source category

GHG emissions / sinks; shares for various GHG, not including CO_2 from LULUCF (%)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
CO_2 emissions (not including LULUCF)	84.09	84.19	83.67	83.49	83.45	83.61	84.07	84.20	85.45	85.53	85.97	86.32	86.49	86.88	86.90	87.08	87.61	87.32	87.40	86.75	88.22	87.91	87.96	88.26
CH_4	9.58	9.49	9.61	9.73	9.55	9.38	9.01	8.91	8.64	8.87	8.60	8.13	7.92	7.62	7.25	7.11	6.66	6.59	6.49	6.73	6.39	6.41	6.46	6.24
N_2O	5.27	5.27	5.58	5.38	5.55	5.50	5.52	5.44	4.37	4.18	4.18	4.25	4.26	4.24	4.52	4.42	4.36	4.68	4.72	4.98	3.94	4.17	4.06	4.00
HFC	0.46	0.44	0.48	0.67	0.72	0.74	0.67	0.75	0.83	0.87	0.77	0.86	0.94	0.88	0.92	0.96	0.98	1.01	1.03	1.17	1.08	1.13	1.15	1.13
PFC	0.24	0.22	0.21	0.20	0.17	0.19	0.18	0.15	0.16	0.14	0.09	0.08	0.09	0.10	0.10	0.08	0.07	0.06	0.06	0.04	0.04	0.03	0.03	0.03
SF_6	0.35	0.39	0.45	0.52	0.56	0.58	0.54	0.55	0.55	0.41	0.39	0.35	0.30	0.29	0.32	0.33	0.32	0.33	0.30	0.32	0.32	0.34	0.34	0.34
NF_3	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0006	0.0007	0.0007	0.0006	0.0009	0.0007	0.0012	0.0019	0.0022	0.0035	0.0028	0.0012	0.0030	0.0032	0.0065	0.0066	0.0038	0.0018
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

GHG emissions / sinks; shares for emission & sink categories, not including CO_2 from LULUCF (%)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
1. Energy	82.99	83.15	82.56	82.42	81.81	81.88	82.45	82.22	83.27	83.58	83.45	84.19	84.32	84.13	83.82	83.93	84.23	83.86	84.18	84.07	85.15	84.68	84.99	85.40
2. Industrial processes	7.71	7.69	8.03	8.18	8.82	8.68	8.39	8.67	7.60	7.07	7.36	6.94	6.96	7.35	7.67	7.54	7.55	7.88	7.47	7.17	6.61	6.81	6.67	6.44
4. Agriculture	6.23	5.87	5.93	5.90	5.89	6.03	5.93	6.04	6.17	6.45	6.42	6.29	6.21	6.14	6.24	6.34	6.20	6.31	6.53	6.94	6.59	6.91	6.82	6.74
4. Land use, land-use changes & forestry (N_2O)	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.17	0.17	0.16	0.17	0.17	0.17	0.17	0.17	0.18	0.18	0.19	0.19	0.19	0.19	0.19
5. Waste	2.91	3.14	3.33	3.34	3.32	3.25	3.08	2.92	2.80	2.74	2.60	2.42	2.34	2.21	2.11	2.02	1.85	1.77	1.65	1.64	1.46	1.41	1.33	1.22
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 436: Emissions of direct and indirect greenhouse gases and SO_2 in Germany since 1990

Emissions (Gg)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Net CO_2 emissions / removals	1,016,520	980,921	932,095	922,883	903,592	902,060	922,294	892,956	884,702	856,401	858,304	873,773	892,759	892,127	874,592
CO_2 emissions (not including LULUCF)	1,050,885	1,012,909	964,648	955,113	938,939	938,024	958,363	930,802	922,815	895,425	899,386	915,682	899,265	900,522	885,910
CH_4	4,790	4,567	4,430	4,452	4,299	4,212	4,108	3,940	3,734	3,713	3,598	3,451	3,295	3,158	2,957
N_2O	221	213	216	207	209	207	211	202	158	147	147	151	149	147	154
HFC (CO_2-eq.)	5,754	5,278	5,501	7,695	8,156	8,354	7,694	8,324	8,935	9,100	8,020	9,109	9,780	9,087	9,375
PFC (CO_2-eq.)	3,060	2,655	2,407	2,256	1,919	2,086	2,041	1,653	1,782	1,485	956	870	946	1,016	977
SF_6 (CO_2-eq.)	4,428	4,746	5,238	5,974	6,249	6,467	6,162	6,109	5,889	4,290	4,072	3,752	3,087	3,034	3,244
NF_3 (CO_2-eq.)	7	7	7	7	7	5	7	8	8	7	9	8	12	19	23
NO_X	2,886	2,643	2,495	2,389	2,201	2,168	2,097	2,032	2,008	1,984	1,928	1,850	1,773	1,717	1,649
SO_2	5,307	3,923	3,196	2,846	2,377	1,704	1,442	1,206	971	793	645	625	562	534	496
NMVOC	3,392	2,906	2,671	2,519	2,014	2,026	1,959	1,933	1,891	1,749	1,599	1,499	1,430	1,360	1,368
CO	12,582	10,348	8,965	8,162	6,808	6,447	5,994	5,858	5,418	5,061	4,816	4,629	4,357	4,176	3,941

Emissions (Gg)	2005	2006	2007	2008	2009	2010	2011	2012	2013
Net CO_2 emissions / removals	852,040	863,457	836,766	832,524	768,407	813,702	793,809	800,397	823,125
CO_2 emissions (not including LULUCF)	865,931	877,971	850,861	854,061	789,107	833,112	812,665	817,913	840,605
CH_4	2,827	2,669	2,570	2,538	2,449	2,414	2,371	2,403	2,379
N_2O	148	147	153	155	152	125	129	127	128
HFC (CO_2-eq.)	9,581	9,784	9,885	10,081	10,660	10,242	10,485	10,710	10,742
PFC (CO_2-eq.)	837	668	586	565	405	344	277	241	257
SF_6 (CO_2-eq.)	3,320	3,242	3,181	2,971	2,924	3,047	3,163	3,155	3,261
NF_3 (CO_2-eq.)	34	28	12	30	29	61	61	35	17
NO_X	1,574	1,558	1,484	1,411	1,311	1,333	1,309	1,268	1,267
SO_2	472	478	461	462	412	434	431	417	416
NMVOC	1,340	1,325	1,265	1,216	1,130	1,238	1,168	1,136	1,138
CO	3,737	3,672	3,590	3,512	3,099	3,544	3,462	3,063	3,089

Table 437: Changes in emissions of direct and indirect greenhouse gases and SO_2 in Germany, since 1990

Emissions Trends Changes compared to base year (%)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Net CO_2 emissions/removals	0.0	-3.5	-8.3	-9.2	-11.1	-11.3	-9.3	-12.2	-13.0	-15.8	-15.6	-14.0	-12.2	-12.2	-14.0	-16.2	-15.1	-17.7	-18.1	-24.4	-20.0	-21.9	-21.3	-19.0
CO_2 emissions (without LULUCF)	0.0	-3.6	-8.2	-9.1	-10.7	-10.7	-8.8	-11.4	-12.2	-14.8	-14.4	-12.9	-14.4	-14.3	-15.7	-17.6	-16.5	-19.0	-18.7	-24.9	-20.7	-22.7	-22.2	-20.0
CH_4	0.0	-4.7	-7.5	-7.1	-10.3	-12.1	-14.2	-17.7	-22.0	-22.5	-24.9	-27.9	-31.2	-34.1	-38.3	-41.0	-44.3	-46.3	-47.0	-48.9	-49.6	-50.5	-49.8	-50.3
N_2O	0.0	-3.7	-2.2	-6.4	-5.2	-6.2	-4.3	-8.7	-28.3	-33.5	-33.6	-31.5	-32.7	-33.3	-30.1	-33.2	-33.6	-30.7	-30.0	-31.2	-43.4	-41.4	-42.7	-42.1
HFC						0.0	-7.9	-0.4	+7.0	+8.9	-4.0	+9.0	+17.1	+8.8	+12.2	+14.7	+17.1	+18.3	+20.7	+27.6	+22.6	+25.5	+28.2	+28.6
PFC						0.0	-2.1	-20.7	-14.6	-28.8	-54.1	-58.3	-54.7	-51.3	-53.1	-59.9	-68.0	-71.9	-72.9	-80.6	-83.5	-86.7	-88.5	-87.7
SF_6						0.0	-4.7	-5.5	-8.9	-33.7	-37.0	-42.0	-52.3	-53.1	-49.8	-48.7	-49.9	-50.8	-54.1	-54.8	-52.9	-51.1	-51.2	-49.6
NF_3						0.0	+36.5	+48.4	+43.4	+26.4	+68.6	+47.8	+131.0	+266.3	+331.3	+552.0	+426.3	+127.3	+459.5	+449.8	+1061.4	+1057.1	+565.6	+216.1
Total Emissions/Removals with LULUCF	0.0	-3.9	-8.1	-8.8	-10.6	-10.9	-9.4	-12.4	-14.5	-17.3	-17.6	-16.4	-15.2	-15.7	-17.3	-19.6	-19.0	-21.2	-21.6	-27.1	-24.1	-25.7	-25.2	-23.3
Total Emissions without CO_2 from LULUCF	0.0	-4.0	-8.0	-8.7	-10.2	-10.5	-9.1	-11.8	-13.8	-16.5	-16.5	-15.4	-17.0	-17.3	-18.7	-20.7	-20.0	-22.3	-22.0	-27.4	-24.7	-26.2	-25.8	-24.0
NO_X	0.0	-8.4	-13.5	-17.2	-23.7	-24.9	-27.3	-29.6	-30.4	-31.3	-33.2	-35.9	-38.6	-40.5	-42.8	-45.5	-46.0	-48.6	-51.1	-54.6	-53.8	-54.7	-56.0	-56.1
SO_2	0.0	-26.1	-39.8	-46.4	-55.2	-67.9	-72.8	-77.3	-81.7	-85.1	-87.8	-88.2	-89.4	-89.9	-90.7	-91.1	-91.0	-91.3	-91.3	-92.2	-91.8	-91.9	-92.2	-92.2
NMVOC	0.0	-14.3	-21.2	-25.7	-40.6	-40.3	-42.2	-43.0	-44.3	-48.4	-52.9	-55.8	-57.9	-59.9	-59.7	-60.5	-60.9	-62.7	-64.2	-66.7	-63.5	-65.5	-66.5	-66.5
CO	0.0	-17.8	-28.7	-35.1	-45.9	-48.8	-52.4	-53.4	-56.9	-59.8	-61.7	-63.2	-65.4	-66.8	-68.7	-70.3	-70.8	-71.5	-72.1	-75.4	-71.8	-72.5	-75.7	-75.4

Table 438: Changes in emissions of direct and indirect greenhouse gases and SO_2 in Germany, since the relevant previous year

Emissions Trends Changes compared to previous year (%)	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Net CO_2 emissions/removals	0.0	-3.5	-5.0	-1.0	-2.1	-0.2	+2.2	-3.2	-0.9	-3.2	+0.2	+1.8	+2.2	-0.1	-2.0	-2.6	+1.3	-3.1	-0.5	-7.7	+5.9	-2.4	+0.8	+2.8
CO_2 emissions (without LULUCF)	0.0	-3.6	-4.8	-1.0	-1.7	-0.1	+2.2	-2.9	-0.9	-3.0	+0.4	+1.8	-1.8	+0.1	-1.6	-2.3	+1.4	-3.1	+0.4	-7.6	+5.6	-2.5	+0.6	+2.8
CH_4	0.0	-4.7	-3.0	+0.5	-3.4	-2.0	-2.5	-4.1	-5.2	-0.6	-3.1	-4.1	-4.5	-4.2	-6.4	-4.4	-5.6	-3.7	-1.3	-3.5	-1.4	-1.8	+1.4	-1.0
N_2O	0.0	-3.7	+1.6	-4.3	+1.3	-1.1	+2.0	-4.6	-21.5	-7.3	-0.0	+3.1	-1.8	-0.8	+4.8	-4.4	-0.6	+4.3	+1.0	-1.8	-17.7	+3.5	-2.1	+1.0
HFC	0.0	-8.3	+4.2	+39.9	+6.0	+2.4	-7.9	+8.2	+7.3	+1.8	-11.9	+13.6	+7.4	-7.1	+3.2	+2.2	+2.1	+1.0	+2.0	+5.7	-3.9	+2.4	+2.1	+0.3
PFC	0.0	-13.3	-9.3	-6.3	-15.0	+8.7	-2.1	-19.0	+7.8	-16.7	-35.6	-9.1	+8.7	+7.4	-3.8	-14.4	-20.2	-12.2	-3.7	-28.4	-15.0	-19.5	-13.1	+6.7
SF_6	0.0	+7.2	+10.4	+14.0	+4.6	+3.5	-4.7	-0.9	-3.6	-27.2	-5.1	-7.9	-17.7	-1.7	+6.9	+2.4	-2.4	-1.9	-6.6	-1.6	+4.2	+3.8	-0.3	+3.4
NF_3	0.0	+0.0	+0.0	+0.0	+0.0	-23.1	+36.5	+8.7	-3.4	-11.9	+33.4	-12.3	+56.2	+58.6	+17.7	+51.2	-19.3	-56.8	+146.2	-1.7	+111.2	-0.4	-42.5	-52.5
Total Emissions /Removals with LULUCF	0.0	-3.6	-4.3	-0.8	-2.0	-0.3	+1.6	-3.3	-2.4	-3.3	-0.3	+1.4	+1.4	-0.5	-1.9	-2.7	+0.7	-2.8	-0.5	-7.0	+4.1	-2.1	+0.7	+2.5
Total Emissions without CO_2 from LULUCF	0.0	-3.7	-4.2	-0.8	-1.6	-0.3	+1.6	-3.0	-2.3	-3.1	-0.1	+1.4	-2.0	-0.3	-1.6	-2.5	+0.8	-2.8	+0.3	-6.9	+3.8	-2.1	+0.6	+2.4
NO_X	0.0	-8.4	-5.6	-4.3	-7.8	-1.5	-3.3	-3.1	-1.2	-1.2	-2.8	-4.0	-4.2	-3.1	-3.9	-4.6	-1.0	-4.7	-4.9	-7.1	+1.7	-1.8	-3.1	-0.1
SO_2	0.0	-26.1	-18.5	-11.0	-16.5	-28.3	-15.4	-16.3	-19.5	-18.3	-18.7	-3.1	-10.0	-4.9	-7.2	-4.9	+1.3	-3.4	+0.0	-10.7	+5.3	-0.8	-3.3	-0.1
NMVOC	0.0	-14.3	-8.1	-5.7	-20.0	+0.6	-3.3	-1.3	-2.2	-7.5	-8.6	-6.3	-4.6	-4.8	+0.6	-2.1	-1.1	-4.5	-3.9	-7.0	+9.6	-5.6	-2.8	+0.2
CO	0.0	-17.8	-13.4	-9.0	-16.6	-5.3	-7.0	-2.3	-7.5	-6.6	-4.8	-3.9	-5.9	-4.1	-5.6	-5.2	-1.7	-2.2	-2.2	-11.8	+14.4	-2.3	-11.5	+0.8

Table 439: Changes in greenhouse-gas emissions in Germany, by source categories, since 1990 / since the relevant previous year

Emissions change with respect to 1990 (%)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
1. Energy	0.0%	-3.5%	-8.2%	-9.1%	-11.2%	-11.4%	-9.4%	-12.4%	-13.3%	-15.6%	-15.8%	-13.9%	-15.5%	-15.9%	-17.6%	-19.5%	-18.6%	-21.2%	-20.7%	-26.3%	-22.5%	-24.5%	-23.8%	-21.6%
2. Industrial processes	0.0%	-7.5%	-7.5%	-6.5%	-0.9%	-2.7%	-4.5%	-4.2%	-18.0%	-26.0%	-23.1%	-26.4%	-27.7%	-23.9%	-21.9%	-25.1%	-24.4%	-23.3%	-27.1%	-34.8%	-37.7%	-37.1%	-38.0%	-38.7%
3. Agriculture	0.0%	-9.4%	-12.3%	-13.3%	-15.0%	-13.1%	-13.2%	-14.3%	-14.4%	-13.4%	-13.8%	-14.4%	-17.1%	-18.2%	-18.3%	-19.1%	-20.2%	-21.0%	-18.1%	-19.0%	-20.1%	-18.0%	-18.6%	-17.5%
4. Land use, land-use changes & forestry (N_2O & CH_4)	0.0%	-0.6%	0.7%	-1.0%	-1.5%	-2.0%	-2.0%	-2.7%	-3.1%	-3.4%	-3.7%	-4.7%	-5.4%	-5.7%	-6.9%	-7.7%	-7.1%	-6.7%	-6.0%	-5.3%	-4.7%	-4.1%	-3.4%	-2.6%
5. Waste	0.0%	3.8%	5.3%	4.9%	2.7%	0.1%	-3.7%	-11.4%	-17.0%	-21.2%	-25.3%	-29.6%	-33.2%	-37.2%	-41.0%	-44.8%	-49.2%	-52.6%	-55.8%	-59.1%	-62.1%	-64.1%	-66.1%	-68.1%
Emissions change, in each case with respect to the previous year; change in %	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
1. Energy	0.0%	-3.5%	-4.9%	-0.9%	-2.4%	-0.2%	2.3%	-3.3%	-1.1%	-2.7%	-0.2%	2.3%	-1.8%	-0.5%	-2.0%	-2.3%	1.1%	-3.2%	0.7%	-7.0%	5.2%	-2.7%	0.9%	2.9%
2. Industrial processes	0.0%	-4.0%	0.0%	1.1%	6.0%	-1.8%	-1.8%	0.3%	-14.4%	-9.8%	4.0%	-4.3%	-1.8%	5.3%	2.6%	-4.1%	1.0%	1.4%	-4.9%	-10.6%	-4.3%	0.9%	-1.4%	-1.1%
3. Agriculture	0.0%	-9.4%	-3.2%	-1.2%	-1.9%	2.1%	0.0%	-1.3%	-0.1%	1.2%	-0.5%	-0.7%	-3.2%	-1.4%	-0.1%	-0.9%	-1.5%	-1.0%	3.7%	-1.1%	-1.3%	2.5%	-0.7%	1.3%
4. Land use, land-use changes & forestry (N_2O & CH_4)	0.0%	-0.6%	1.3%	-1.7%	-0.5%	-0.5%	0.0%	-0.7%	-0.4%	-0.3%	-0.3%	-1.0%	-0.8%	-0.2%	-1.3%	-0.9%	0.7%	0.4%	0.7%	0.8%	0.6%	0.6%	0.7%	0.9%
5. Waste	0.0%	3.8%	1.5%	-0.4%	-2.1%	-2.5%	-3.8%	-8.1%	-6.3%	-5.1%	-5.1%	-5.8%	-5.1%	-6.0%	-6.0%	-6.5%	-8.0%	-6.7%	-6.9%	-7.3%	-7.3%	-5.4%	-5.5%	-5.9%

23 ANNEX 7: TABLE 6.1 OF THE IPCC GOOD PRACTICE GUIDANCE

The uncertainties for the German greenhouse-gas inventories have been determined completely, for all categories.

Efforts in this area, which began with determination of uncertainties pursuant to Tier 1, are being carried out by data-supplying experts of Federal Environment Agency departments and by external institutions.

At the same time, additional uncertainties have been determined via experts' assessments and added to the CSE database. An uncertainties data set is now available in which most of the uncertainties have been determined via expert estimation. In cases in which experts' assessments are not yet available, a complete data set is obtained by adopting uncertainties from data reported in the relevant technical literature. The expert assessment process is being continued, systematically and completely.

Germany carries out Tier 2 uncertainties analysis every 3 years.

The results of this year's Tier 1 uncertainties analysis are shown, in keeping with the specifications given in Table 3.2 of the 2006 IPCC Guidelines, in Table 440.

Table 440: Table 6.1 of the IPCC Good Practice Guidance – details

CRF	Category	Gas	Base-year emissions [t CO_2-eq.]	Emissions, 2012 [Gg CO_2-eq.]	Combined uncertainty of activity data [%]	Combined uncertainty of emission factors [%]	Combined uncertainty of emissions [%]	Combined uncertainty percentage [%]	Trend uncertainty for emission factors [%]	Trend uncertainty for activity data [%]	Trend uncertainty for emissions [%]
1.A.1.a	All fuels	Methane	244,770.58	2,230,233.61	0.00E+00	0.00E+00	7.22E+01	2.97E-02	0.00E+00	0.00E+00	0.00E+00
1.A.1.a	All fuels	Carbon dioxide	304,600,111.60	328,385,058.03	4.20E+00	1.88E+00	4.60E+00	2.61E+00	8.09E-01	1.80E+00	3.91E+00
1.A.1.a	All fuels	Nitrous oxide	2,109,962.22	2,546,303.71	0.00E+00	0.00E+00	2.09E+01	3.24E-03	0.00E+00	0.00E+00	0.00E+00
1.A.1.b	All fuels	Carbon dioxide	19,131,148.49	17,993,637.24	3.11E+00	4.96E+00	5.86E+00	1.27E-02	1.17E-01	7.32E-02	1.90E-02
1.A.1.b	All fuels	Methane	14,926.14	12,877.73	0.00E+00	0.00E+00	1.62E+01	4.99E-08	0.00E+00	0.00E+00	0.00E+00
1.A.1.b	All fuels	Nitrous oxide	62,566.66	54,606.69	0.00E+00	0.00E+00	3.13E+01	3.33E-06	0.00E+00	0.00E+00	0.00E+00
1.A.1.c	All fuels	Methane	135,624.34	13,906.56	0.00E+00	0.00E+00	1.21E+02	3.26E-06	0.00E+00	0.00E+00	0.00E+00
1.A.1.c	All fuels	Nitrous oxide	357,751.55	150,147.96	0.00E+00	0.00E+00	2.28E+01	1.34E-05	0.00E+00	0.00E+00	0.00E+00
1.A.1.c	All fuels	Carbon dioxide	40,220,507.25	10,267,475.70	4.09E+00	2.99E+00	5.07E+00	3.10E-03	4.02E-02	5.50E-02	4.64E-03
1.A.2.a	All fuels	Methane	61,215.46	73,913.16	0.00E+00	0.00E+00	2.66E+01	4.42E-06	0.00E+00	0.00E+00	0.00E+00
1.A.2.a	All fuels	Nitrous oxide	118,100.49	123,116.77	0.00E+00	0.00E+00	3.73E+01	2.41E-05	0.00E+00	0.00E+00	0.00E+00
1.A.2.a	All fuels	Carbon dioxide	33,097,558.64	34,080,948.26	4.22E+00	2.88E+00	5.11E+00	3.47E-02	1.29E-01	1.88E-01	5.19E-02
1.A.2.b	All fuels	Carbon dioxide	2,051,868.53	1,564,572.92	1.09E+01	9.26E-01	1.09E+01	3.36E-04	1.90E-03	2.23E-02	5.03E-04
1.A.2.b	All fuels	Methane	1,730.36	1,736.94	0.00E+00	0.00E+00	6.95E+01	1.67E-08	0.00E+00	0.00E+00	0.00E+00
1.A.2.b	All fuels	Nitrous oxide	13,862.87	8,060.68	0.00E+00	0.00E+00	6.48E+01	3.12E-07	0.00E+00	0.00E+00	0.00E+00
1.A.2.d	All fuels	Carbon dioxide	6,869.00	7,798.74	5.22E+00	2.24E+00	5.68E+00	2.24E-09	2.28E-05	5.33E-05	3.36E-09
1.A.2.d	All fuels	Methane	1,099.83	2,731.25	0.00E+00	0.00E+00	4.40E+01	1.65E-08	0.00E+00	0.00E+00	0.00E+00
1.A.2.d	All fuels	Nitrous oxide	4,719.59	11,720.34	0.00E+00	0.00E+00	5.27E+01	4.37E-07	0.00E+00	0.00E+00	0.00E+00
1.A.2.e	All fuels	Carbon dioxide	1,986,645.42	303,752.74	4.48E+00	1.93E+00	4.88E+00	2.52E-06	7.68E-04	1.78E-03	3.77E-06
1.A.2.e	All fuels	Methane	2,040.08	261.64	0.00E+00	0.00E+00	4.14E+01	1.34E-10	0.00E+00	0.00E+00	0.00E+00
1.A.2.e	All fuels	Nitrous oxide	18,655.95	3,173.20	0.00E+00	0.00E+00	5.67E+01	3.71E-08	0.00E+00	0.00E+00	0.00E+00
1.A.2.f	All fuels	Carbon dioxide	18,595,352.46	13,072,757.26	3.73E+00	9.88E-01	3.86E+00	2.91E-03	1.69E-02	6.38E-02	4.36E-03
1.A.2.f	All fuels	Methane	18,003.83	15,065.57	0.00E+00	0.00E+00	2.24E+01	1.30E-07	0.00E+00	0.00E+00	0.00E+00
1.A.2.f	All fuels	Nitrous oxide	173,555.06	121,653.61	0.00E+00	0.00E+00	2.71E+01	1.24E-05	0.00E+00	0.00E+00	0.00E+00
1.A.2.g	All fuels	Carbon dioxide	88,778,224.90	76,159,993.92	5.18E+00	9.65E-01	5.27E+00	1.84E-01	9.62E-02	5.16E-01	2.76E-01
1.A.2.g	All fuels	Methane	138,498.20	171,662.81	7.64E-01	2.60E-01	2.87E+01	2.78E-05	5.84E-05	1.72E-04	3.29E-08
1.A.2.g	All fuels	Nitrous oxide	645,677.93	525,777.18	6.28E+00	8.79E+00	1.66E+01	8.74E-05	6.05E-03	4.32E-03	5.52E-05
1.A.3.a	Aviation gasoline	Carbon dioxide	2,191,938.41	2,068,523.61	7.44E+00	3.72E+00	8.31E+00	3.38E-04	1.01E-02	2.01E-02	5.07E-04
1.A.3.a	Aviation gasoline	Methane	2,348.44	1,869.40	9.46E+00	9.47E+01	9.52E+01	3.62E-08	2.32E-04	2.32E-05	5.43E-08
1.A.3.a	Aviation gasoline	Nitrous oxide	22,031.56	20,637.62	7.28E+00	1.09E+02	1.09E+02	5.83E-06	2.95E-03	1.97E-04	8.74E-06
1.A.3.b	All fuels	Carbon dioxide	166,411,751.77	151,347,615.26	9.28E+00	7.45E-01	9.31E+00	2.27E+00	1.48E-01	1.84E+00	3.40E+00
1.A.3.b	All fuels	Methane	727,990.38	146,527.41	2.07E+01	3.50E+01	4.07E+01	4.07E-05	6.72E-03	3.98E-03	6.10E-05
1.A.3.b	All fuels	Nitrous oxide	1,607,638.94	1,426,632.90	9.54E+00	2.66E+01	2.83E+01	1.86E-03	4.97E-02	1.78E-02	2.79E-03
1.A.3.c	All fuels	Carbon dioxide	2,330,576.72	998,936.10	9.71E+00	2.91E+00	1.01E+01	1.17E-04	3.80E-03	1.27E-02	1.76E-04
1.A.3.c	All fuels	Methane	1,994.99	646.21	8.56E+00	2.72E+01	2.85E+01	3.89E-10	2.30E-05	7.24E-06	5.82E-10
1.A.3.c	All fuels	Nitrous oxide	5,582.80	2,698.91	8.60E+00	6.17E+01	6.23E+01	3.24E-08	2.18E-04	3.04E-05	4.85E-08
1.A.3.d	Diesel oil	Carbon dioxide	2,850,531.36	1,747,742.61	1.81E+01	1.91E+00	1.82E+01	1.16E-03	4.36E-03	4.15E-02	1.74E-03

CRF	Category	Gas	Base-year emissions [t CO_2-eq.]	Emissions, 2012 [Gg CO_2-eq.]	Combined uncertainty of activity data [%]	Combined uncertainty of emission factors [%]	Combined uncertainty of emissions [%]	Combined uncertainty percentage [%]	Trend uncertainty for emission factors [%]	Trend uncertainty for activity data [%]	Trend uncertainty for emissions [%]
1.A.3.d	Diesel oil	Methane	1,473.39	652.70	2.05E+01	2.44E+01	3.19E+01	4.96E-10	2.09E-05	1.75E-05	7.44E-10
1.A.3.d	Diesel oil	Nitrous oxide	24,651.82	17,838.26	1.36E+01	8.60E+01	8.71E+01	2.76E-06	2.01E-03	3.18E-04	4.14E-06
1.A.3.e	All fuels	Carbon dioxide	1,329,440.00	1,471,240.85	2.79E+00	9.32E-01	2.95E+00	2.15E-05	1.79E-03	5.38E-03	3.22E-05
1.A.3.e	All fuels	Methane	6,486.96	7,175.82	0.00E+00	0.00E+00	6.99E+01	2.88E-07	0.00E+00	0.00E+00	0.00E+00
1.A.3.e	All fuels	Nitrous oxide	17,686.30	12,808.64	0.00E+00	0.00E+00	4.84E+01	4.39E-07	0.00E+00	0.00E+00	0.00E+00
1.A.4.a	All fuels	Carbon dioxide	53,424,456.61	40,557,072.37	7.71E+00	1.13E+00	7.79E+00	1.14E-01	6.01E-02	4.09E-01	1.71E-01
1.A.4.a	All fuels	Methane	246,309.95	45,048.14	6.36E-01	1.22E+00	1.21E+02	3.41E-05	7.20E-05	3.75E-05	6.60E-09
1.A.4.a	All fuels	Nitrous oxide	131,732.50	91,886.30	5.97E+00	8.47E+00	9.37E+01	8.49E-05	1.02E-03	7.19E-04	1.56E-06
1.A.4.b	All fuels	Carbon dioxide	128,974,819.19	102,892,351.29	8.34E+00	1.29E+00	8.44E+00	8.63E-01	1.74E-01	1.12E+00	1.29E+00
1.A.4.b	All fuels	Methane	654,665.62	750,831.22	8.77E-01	3.51E-01	1.47E+02	1.40E-02	3.45E-04	8.62E-04	8.61E-07
1.A.4.b	All fuels	Nitrous oxide	457,120.57	346,142.36	3.46E-01	6.88E-01	7.63E+01	7.98E-04	3.12E-04	1.57E-04	1.22E-07
1.A.4.c	All fuels	Carbon dioxide	7,710,128.84	5,651,526.95	5.98E+01	1.90E+00	5.99E+01	1.31E-01	1.41E-02	4.43E-01	1.96E-01
1.A.4.c	All fuels	Methane	55,344.78	570,012.69	6.62E-01	3.19E-01	7.31E+01	1.99E-03	2.38E-04	4.94E-04	3.01E-07
1.A.4.c	All fuels	Nitrous oxide	52,126.70	85,017.61	4.58E+01	6.42E+01	9.78E+01	7.92E-05	7.14E-03	5.10E-03	7.71E-05
1.A.5	All fuels	Carbon dioxide	4,004,388.36	1,039,197.26	5.43E+00	1.37E+00	5.60E+00	3.88E-05	1.86E-03	7.39E-03	5.81E-05
1.A.5	All fuels	Methane	14,033.41	1,422.70	2.58E+00	2.04E+01	2.99E+01	2.07E-09	3.81E-05	4.80E-06	1.47E-09
1.A.5	All fuels	Nitrous oxide	27,281.60	3,622.46	8.40E+00	6.23E+01	6.83E+01	7.01E-08	2.95E-04	3.98E-05	8.88E-08
1.B.1	Solid fuels	Carbon dioxide	933,058.59	706,966.53	1.12E+00	1.87E+01	3.64E+01	7.60E-04	1.73E-02	1.04E-03	3.01E-04
1.B.1	Solid fuels	Methane	19,347,784.96	3,580,159.60	0.00E+00	0.00E+00	3.68E+01	1.99E-02	0.00E+00	0.00E+00	0.00E+00
1.B.2.a	Liquid fuels	Carbon dioxide	278,409.07	310,811.76	2.06E+01	2.06E+01	2.95E+01	9.62E-05	8.40E-03	8.40E-03	1.41E-04
1.B.2.a	Liquid fuels	Methane	311,168.39	234,787.88	0.00E+00	0.00E+00	2.86E+01	5.14E-05	0.00E+00	0.00E+00	0.00E+00
1.B.2.b	Gaseous fuels	Carbon dioxide	1,760,298.38	1,598,256.18	0.00E+00	0.00E+00	2.23E+01	1.46E-03	0.00E+00	0.00E+00	0.00E+00
1.B.2.b	Gaseous fuels	Methane	9,746,639.08	7,428,994.33	8.55E-03	8.55E-03	2.32E+01	3.39E-02	8.31E-05	8.31E-05	1.38E-08
1.B.2.c		Carbon dioxide	437,759.96	367,848.47	0.00E+00	0.00E+00	1.25E+02	2.42E-03	0.00E+00	0.00E+00	0.00E+00
1.B.2.c		Methane	1,851.64	2,598.32	0.00E+00	0.00E+00	3.72E+01	1.07E-08	0.00E+00	0.00E+00	0.00E+00
1.B.2.c		Nitrous oxide	547.28	171.23	0.00E+00	0.00E+00	1.52E+01	7.78E-12	0.00E+00	0.00E+00	0.00E+00
2.A.1		Carbon dioxide	15,408,313.70	12,257,822.66	0.00E+00	0.00E+00	3.20E+00	1.76E-03	0.00E+00	0.00E+00	0.00E+00
2.A.2		Carbon dioxide	6,159,875.94	4,811,302.14	2.40E+00	1.06E+01	1.09E+01	3.15E-03	6.70E-02	1.51E-02	4.71E-03
2 A 3 glass		Carbon dioxide	881,306.26	875,407.70	3.07E+00	1.09E+01	1.14E+01	1.13E-04	1.25E-02	3.52E-03	1.70E-04
2.A.4 other		Carbon dioxide	759,810.71	568,132.69	7.66E+00	2.13E+00	1.92E+01	1.37E-04	1.58E-03	5.70E-03	3.50E-05
2.B.1		Carbon dioxide	6,528,000.00	6,739,000.00	0.00E+00	0.00E+00	1.00E+00	5.20E-05	0.00E+00	0.00E+00	0.00E+00
2.B.10		Nitrous oxide	59,600.00	59,600.00	3.00E+02	7.50E+01	3.09E+02	3.89E-04	5.85E-03	2.34E-02	5.82E-04
2.B.2		Nitrous oxide	3,325,908.76	480,370.53	1.00E+00	5.00E+00	5.10E+00	6.87E-06	3.14E-03	6.29E-04	1.03E-05
2.B.3		Nitrous oxide	20,234,334.32	338,257.39	2.00E+00	6.00E+00	6.32E+00	5.24E-06	2.66E-03	8.86E-04	7.84E-06
2.B.5		Carbon dioxide	25,806.00	10,942.97	1.00E+01	1.00E+01	1.41E+01	2.74E-08	1.43E-04	1.43E-04	4.10E-08
2.B.7		Carbon dioxide	537,004.51	471,325.54	0.00E+00	0.00E+00	2.50E+00	1.59E-06	0.00E+00	0.00E+00	0.00E+00
2.B.8		Carbon dioxide	768,895.83	1,980,179.31	1.40E+01	1.40E+01	2.14E+01	2.05E-03	3.64E-02	3.64E-02	2.65E-03

CRF	Category	Gas	Base-year emissions [t CO_2-eq.]	Emissions, 2012 [Gg CO_2-eq.]	Combined uncertainty of activity data [%]	Combined uncertainty of emission factors [%]	Combined uncertainty of emissions [%]	Combined uncertainty percentage [%]	Trend uncertainty for emission factors [%]	Trend uncertainty for activity data [%]	Trend uncertainty for emissions [%]
2.B.8		Methane	428,414.10	464,007.59	2.29E-02	3.06E-03	2.09E+01	1.08E-04	1.86E-06	1.39E-05	1.97E-10
2.B.9		Sulphur hexafluoride	159,600.00	101,004.00	0.00E+00	0.00E+00	1.00E+01	1.17E-06	0.00E+00	0.00E+00	0.00E+00
2.B.9		Hydrofluorocarbons	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2.C.1		Methane	6,997.29	5,265.15	0.00E+00	0.00E+00	6.75E+01	1.44E-07	0.00E+00	0.00E+00	0.00E+00
2.C.1		Carbon dioxide	19,270,069.40	13,978,011.22	7.55E+00	5.87E+00	9.69E+00	2.10E-02	1.07E-01	1.38E-01	3.06E-02
2.C.1		Nitrous oxide	16,777.50	12,758.21	0.00E+00	0.00E+00	7.18E+01	9.60E-07	0.00E+00	0.00E+00	0.00E+00
2.C.2		Carbon dioxide	9,107.45	6,091.14	0.00E+00	0.00E+00	5.05E+01	1.08E-07	0.00E+00	0.00E+00	0.00E+00
2.C.3		CF_4	1,544,510.00	89,788.50	0.00E+00	0.00E+00	1.50E+01	2.08E-06	0.00E+00	0.00E+00	0.00E+00
2.C.3		Sulphur hexafluoride	11,400.00	14,103.40	0.00E+00	0.00E+00	5.00E+01	5.69E-07	0.00E+00	0.00E+00	0.00E+00
2.C.3		C_2F_6	256,200.00	17,873.00	0.00E+00	0.00E+00	1.50E+01	8.26E-08	0.00E+00	0.00E+00	0.00E+00
2.C.3.a		Carbon dioxide	786,025.00	673,067.06	0.00E+00	0.00E+00	5.00E+01	1.30E-03	0.00E+00	0.00E+00	0.00E+00
2.C.4		Sulphur hexafluoride	176,631.60	19,836.00	0.00E+00	0.00E+00	3.00E+01	4.06E-07	0.00E+00	0.00E+00	0.00E+00
2.C.4		HFC-134a	0.00	33,028.71	0.00E+00	0.00E+00	3.00E+01	1.13E-06	0.00E+00	0.00E+00	0.00E+00
2.C.5		Carbon dioxide	116,494.00	88,071.50	0.00E+00	0.00E+00	5.05E+01	2.26E-05	0.00E+00	0.00E+00	0.00E+00
2.C.6		Carbon dioxide	612,320.00	279,037.32	0.00E+00	0.00E+00	5.02E+01	2.25E-04	0.00E+00	0.00E+00	0.00E+00
2.D.1		Carbon dioxide	554,368.89	569,870.53	5.96E+00	1.19E+01	4.31E+01	6.91E-04	8.89E-03	4.44E-03	9.87E-05
2.D.2		Carbon dioxide	337,164.66	650,014.32	0.00E+00	0.00E+00	5.39E+01	1.40E-03	0.00E+00	0.00E+00	0.00E+00
2.D.2		Nitrous oxide	822.43	1,585.55	0.00E+00	0.00E+00	5.39E+01	8.34E-09	0.00E+00	0.00E+00	0.00E+00
2.D.3		Carbon dioxide	2,042,612.00	1,401,371.40	0.00E+00	0.00E+00	7.91E+00	1.41E-04	0.00E+00	0.00E+00	0.00E+00
2.E		Sulphur hexafluoride	47,281.67	18,559.20	0.00E+00	0.00E+00	1.12E+01	4.90E-08	0.00E+00	0.00E+00	0.00E+00
2.E		HFC-23	17,112.33	13,542.00	0.00E+00	0.00E+00	1.22E+01	3.2E-08	0.00E+00	0.00E+00	0.00E+00
2.E		$c\text{-}C_4F_8$	0.00	3,800.70	0.00E+00	0.00E+00	1.22E+01	2.6E-09	0.00E+00	0.00E+00	0.00E+00
2.E		Nitrogen trifluoride	5,289.72	16,718.40	0.00E+00	0.00E+00	1.11E+01	3.95E-08	0.00E+00	0.00E+00	0.00E+00
2.E		C_2F_6	162,484.67	48,360.80	0.00E+00	0.00E+00	1.22E+01	3.98E-07	0.00E+00	0.00E+00	0.00E+00
2.E		HFC-32	0.00	39.83	0.00E+00	0.00E+00	1.22E+01	2.70E-13	0.00E+00	0.00E+00	0.00E+00
2.E		C_3F_8	0.00	16,918.28	0.00E+00	0.00E+00	1.22E+01	4.88E-08	0.00E+00	0.00E+00	0.00E+00
2.E		CF_4	102,615.00	70,655.79	0.00E+00	0.00E+00	1.01E+01	5.88E-07	0.00E+00	0.00E+00	0.00E+00
2.F		HFC-134a	2,266,389.49	6,287,532.25	0.00E+00	0.00E+00	5.83E+00	1.54E-03	0.00E+00	0.00E+00	0.00E+00
2.F		C_2F_6	0.00	2,364.57	0.00E+00	0.00E+00	1.62E+01	1.68E-09	0.00E+00	0.00E+00	0.00E+00
2.F		HFC-32	861.88	133,699.26	0.00E+00	0.00E+00	7.71E+00	1.21E-06	0.00E+00	0.00E+00	0.00E+00
2.F		C_3F_8	19,911.19	7,029.67	0.00E+00	0.00E+00	1.90E+01	2.05E-08	0.00E+00	0.00E+00	0.00E+00
2.F		HFC-245fa	0.00	34,765.11	0.00E+00	0.00E+00	1.12E+01	1.73E-07	0.00E+00	0.00E+00	0.00E+00
2.F		HFC-227ea	646.63	69,807.74	0.00E+00	0.00E+00	1.57E+01	1.38E-06	0.00E+00	0.00E+00	0.00E+00
2.F		HFC-365mfc	0.00	42,798.27	0.00E+00	0.00E+00	1.07E+01	2.38E-07	0.00E+00	0.00E+00	0.00E+00
2.F		HFC-236fa	0.00	33,237.29	0.00E+00	0.00E+00	6.27E+01	4.97E-06	0.00E+00	0.00E+00	0.00E+00
2.F		HFC-143a	61,887.43	1,712,397.05	0.00E+00	0.00E+00	1.36E+01	6.22E-04	0.00E+00	0.00E+00	0.00E+00
2.F		HFC-152a	90,070.08	38,854.10	0.00E+00	0.00E+00	3.03E+00	1.58E-08	0.00E+00	0.00E+00	0.00E+00
2.F		HFC-23	16,253.62	97,722.66	0.00E+00	0.00E+00	1.44E+01	2.26E-06	0.00E+00	0.00E+00	0.00E+00
2.F		HFC-125	144,234.39	2,063,158.51	0.00E+00	0.00E+00	9.90E+00	4.77E-04	0.00E+00	0.00E+00	0.00E+00

CRF	Category	Gas	Base-year emissions [t CO_2-eq.]	Emissions, 2012 [Gg CO_2-eq.]	Combined uncertainty of activity data [%]	Combined uncertainty of emission factors [%]	Combined uncertainty of emissions [%]	Combined uncertainty percentage [%]	Trend uncertainty for emission factors [%]	Trend uncertainty for activity data [%]	Trend uncertainty for emissions [%]
2.G		Methane	11,374.09	35,995.00	0.00E+00	0.00E+00	2.83E+01	1.19E-06	0.00E+00	0.00E+00	0.00E+00
2.G		Nitrous oxide	1,572,073.83	338,234.61	3.55E-01	2.36E-02	4.01E+01	2.10E-04	1.05E-05	1.57E-04	2.48E-08
2.G		$C_{10}F_{18}$	0.00	7,036.73	0.00E+00	0.00E+00	2.50E+01	3.54E-08	0.00E+00	0.00E+00	0.00E+00
2.G		Sulphur hexafluoride	6,072,236.26	3,107,630.66	0.00E+00	0.00E+00	8.03E+00	7.12E-04	0.00E+00	0.00E+00	0.00E+00
2.G		HFC-134a	0.00	200.20	0.00E+00	0.00E+00	2.24E+01	2.29E-11	0.00E+00	0.00E+00	0.00E+00
2.G		HFC-245fa	0.00	6,421.66	0.00E+00	0.00E+00	2.22E+01	2.33E-08	0.00E+00	0.00E+00	0.00E+00
2.G		HFC-365mfc	0.00	497.98	0.00E+00	0.00E+00	2.21E+01	1.39E-10	0.00E+00	0.00E+00	0.00E+00
3.A.1.a	Dairy cattle	Methane	16,266,832.39	14,380,588.60	4.00E+00	4.00E+01	4.02E+01	3.82E-01	7.53E-01	7.53E-02	5.73E-01
3.A.1.b	Non-dairy cattle	Methane	11,753,310.83	9,175,966.49	2.37E+00	2.37E+01	2.38E+01	5.45E-02	2.84E-01	2.84E-02	8.16E-02
3.A.2-4 Manure managem ent	Other animals	Methane	1,280,607.12	1,156,278.17	3.46E+00	2.46E+01	2.48E+01	9.44E-04	3.72E-02	5.23E-03	1.41E-03
3.B.1.a	Dairy cattle	Methane	2,778,614.00	2,259,852.39	4.00E+00	4.00E+01	4.02E+01	9.44E-03	1.18E-01	1.18E-02	1.41E-02
3.B.1.a	Dairy cattle	Nitrous oxide	1,179,710.49	1,012,598.55	4.00E+00	1.00E+02	1.00E+02	1.18E-02	1.33E-01	5.30E-03	1.76E-02
3.B.1.b	Non-dairy cattle	Methane	2,133,728.08	1,494,486.77	2.34E+00	2.34E+01	2.35E+01	1.41E-03	4.57E-02	4.57E-03	2.11E-03
3.B.1.b	Non-dairy cattle	Nitrous oxide	1,250,577.16	1,029,566.31	2.23E+00	5.58E+01	5.58E+01	3.78E-03	7.52E-02	3.01E-03	5.66E-03
3.B.5	Manure (atmospheric deposition)	Nitrous oxide	1,046,558.01	1,043,590.51	1.00E+01	4.00E+02	4.00E+02	2.00E-01	5.47E-01	1.37E-02	2.99E-01
3.B.2-4 Manure managem ent	Other animals	Methane	56,261.64	40,139.18	7.78E+00	3.30E+01	3.39E+01	2.12E-06	1.73E-03	4.09E-04	3.17E-06
3.B.2-4 Manure managem ent	Other animals	Nitrous oxide	269,979.07	194,852.15	7.83E+00	2.34E+02	2.35E+02	2.39E-03	5.98E-02	2.00E-03	3.58E-03
3.B.3	Swine	Methane	2,232,859.13	2,403,019.04	3.16E+00	3.16E+01	3.17E+01	6.65E-03	9.93E-02	9.93E-03	9.96E-03
3.B.3	Swine	Nitrous oxide	433,839.87	565,180.41	3.02E+00	7.54E+01	7.54E+01	2.08E-03	5.58E-02	2.23E-03	3.11E-03
3.B.4	Poultry	Nitrous oxide	35,562.00	66,093.32	5.52E+00	5.52E+01	5.55E+01	1.54E-05	4.78E-03	4.78E-04	2.31E-05
3.B.4	Poultry	Methane	85,458.75	146,050.71	5.49E+00	2.20E+01	2.27E+01	1.25E-05	4.20E-03	1.05E-03	1.88E-05
3.D	Agricultural Soils	Nitrous oxide	24,723,253.06	25,278,579.92	2.45E+01	8.84E+01	9.17E+01	6.15E+00	2.92E+00	8.11E-01	9.21E+00
3.G	Liming	Carbon dioxide	1,643,883.28	1,956,470.11	1.00E+00	3.00E+00	3.16E+00	4.38E-05	7.68E-03	2.56E-03	6.56E-05
3.H	Urea application	Carbon dioxide	477,245.21	695,038.93	1.00E+00	1.00E+00	1.41E+00	1.11E-06	9.10E-04	9.10E-04	1.66E-06
3.J	Other	Methane	3,552.65	1,115,378.57	1.00E+01	4.00E+01	4.12E+01	2.42E-03	5.84E-02	1.46E-02	3.62E-03
3.J	Other	Nitrous oxide	1,429.94	228,771.17	9.52E+00	9.71E+01	9.76E+01	5.70E-04	2.91E-02	2.85E-03	8.54E-04
4.A		Carbon dioxide	-75,215,263.74	-56,832,239.84	0.00E+00	0.00E+00	6.75E+01	1.68E+01	0.00E+00	0.00E+00	0.00E+00
4.A		Methane	48,166.53	46,429.54	0.00E+00	0.00E+00	8.80E+02	1.91E-03	0.00E+00	0.00E+00	0.00E+00

CRF	Category	Gas	Base-year emissions [t CO_2-eq.]	Emissions, 2012 [Gg CO_2-eq.]	Combined uncertainty of activity data [%]	Combined uncertainty of emission factors [%]	Combined uncertainty of emissions [%]	Combined uncertainty percentage [%]	Trend uncertainty for emission factors [%]	Trend uncertainty for activity data [%]	Trend uncertainty for emissions [%]
4.A		Nitrous oxide	390,557.61	311,431.48	0.00E+00	0.00E+00	1.50E+02	2.49E-03	0.00E+00	0.00E+00	0.00E+00
4.B		Carbon dioxide	14,980,242.19	13,671,365.55	0.00E+00	0.00E+00	2.96E+01	1.88E-01	0.00E+00	0.00E+00	0.00E+00
4.B		Nitrous oxide	268,094.62	308,973.86	0.00E+00	0.00E+00	2.09E+02	4.78E-03	0.00E+00	0.00E+00	0.00E+00
4.B		Methane	253,233.92	231,076.11	0.00E+00	0.00E+00	1.82E+02	2.03E-03	0.00E+00	0.00E+00	0.00E+00
4.C		Carbon dioxide	21,542,669.74	22,237,573.51	0.00E+00	0.00E+00	5.13E+01	1.49E+00	0.00E+00	0.00E+00	0.00E+00
4.C		Methane	502,683.41	517,611.84	0.00E+00	0.00E+00	2.17E+02	1.45E-02	0.00E+00	0.00E+00	0.00E+00
4.C		Nitrous oxide	18,421.31	19,982.20	0.00E+00	0.00E+00	8.93E+01	3.65E-06	0.00E+00	0.00E+00	0.00E+00
4.D		Carbon dioxide	2,802,534.98	2,452,973.88	0.00E+00	0.00E+00	4.03E+01	1.12E-02	0.00E+00	0.00E+00	0.00E+00
4.D		Methane	11,579.52	12,270.76	0.00E+00	0.00E+00	3.47E+02	2.08E-05	0.00E+00	0.00E+00	0.00E+00
4.D		Nitrous oxide	10,451.13	11,243.54	0.00E+00	0.00E+00	8.18E+01	9.69E-07	0.00E+00	0.00E+00	0.00E+00
4.E		Carbon dioxide	2,474,197.76	3,577,768.20	0.00E+00	0.00E+00	3.07E+01	1.38E-02	0.00E+00	0.00E+00	0.00E+00
4.E		Methane	35,863.16	38,865.19	0.00E+00	0.00E+00	1.47E+02	3.73E-05	0.00E+00	0.00E+00	0.00E+00
4.E		Nitrous oxide	150,640.86	183,564.52	0.00E+00	0.00E+00	1.09E+02	4.57E-04	0.00E+00	0.00E+00	0.00E+00
4.G		Carbon dioxide	-2,549,000.00	-2,588,000.00	0.00E+00	0.00E+00	7.68E+01	4.52E-02	0.00E+00	0.00E+00	0.00E+00
4.H		Nitrous oxide	106,869.94	105,337.94	0.00E+00	0.00E+00	1.78E+02	4.04E-04	0.00E+00	0.00E+00	0.00E+00
5.A		Methane	35,100,000.00	9,850,000.00	0.00E+00	0.00E+00	5.00E+01	2.78E-01	0.00E+00	0.00E+00	0.00E+00
5.B		Methane	180,880.00	737,590.00	1.43E+00	4.29E+01	4.30E+01	1.15E-03	4.15E-02	1.38E-03	1.72E-03
5.B		Nitrous oxide	113,964.74	317,626.88	1.45E+00	7.26E+01	7.26E+01	6.09E-04	3.02E-02	6.04E-04	9.12E-04
5.D.1		Methane	365,692.90	23,811.98	3.00E+01	3.61E+01	4.69E+01	1.43E-06	1.12E-03	9.35E-04	2.14E-06
5.D.1		Nitrous oxide	532,136.52	397,261.67	3.29E+01	3.85E+03	3.85E+03	2.67E+00	2.00E+00	1.71E-02	4.01E+00
5.D.2		Methane	15,520.73	41,430.15	0.00E+00	0.00E+00	5.00E+01	4.91E-06	0.00E+00	0.00E+00	0.00E+00
5.D.2		Nitrous oxide	119,140.47	118,927.22	5.00E+01	3.00E+02	3.04E+02	1.50E-03	4.67E-02	7.78E-03	2.24E-03
5.E		Methane	718.13	5,864.38	2.00E+00	6.00E+01	6.00E+01	1.42E-07	4.61E-04	1.54E-05	2.12E-07
5.E		Nitrous oxide	10,842.73	127,097.00	2.00E+00	6.00E+01	6.00E+01	6.66E-05	9.98E-03	3.33E-04	9.98E-05
Total		**(in Gg / %)**	**1,080,226,291**	**934,812,658**				**3.48E+01**			**2.36E+01**
								5.9 %			**4.9 %**

Uncertainties for categories have been determined successively, within the framework of UBA sections' data deliveries for current emissions reporting. In addition, external experts have carried out additional uncertainties determination, in research projects, for categories for which no uncertainties information, or incomplete information, has been available to date. The results of such uncertainties analysis have been integrated within the current report.

The uncertainties in the category Agriculture (CRF 4) were estimated by experts of the Thünen Institute (TI).

Current work planning calls for Tier 2 uncertainties analysis to be carried out every three years. Uncertainties are determined pursuant to Tier 1, and reported, every year.

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