Submission under the United Nations Framework Convention on Climate Change 2006

National Inventory Report

for the German Greenhouse Gas Inventory 1990 - 2004

Federal Environmental Agency (Umweltbundesamt)

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Kontakt

This report is the result of work by the Federal Environmental Agency (UBA) to develop the *National System of Emissions Inventories* (NaSE) and the *Quality System for Emissions Inventories* (QSE). The information on agriculture, land use changes and forestry was provided by the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) and the Federal Agricultural Research Institute *(Bundesforschungsanstalt für Landwirtschaft, FAL)*.

The electronic version of this report, along with the pertinent emissions data in the Common Reporting Format (CRF), is available on the Website of the Federal Environmental Agency: http://www.umweltbundesamt.de/emissionen/veroeffentlichungen.htm

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Notice:

Number formats in tables and figures in this document are kept conform to german standards due to technical restrictions: the comma is used as the decimal separator, the point as the thousands separator in large numbers.

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List of Abbreviations

(The abbreviations for CSE structural elements are listed in Table 15)

AbfAblV	Ordinance on Environmentally Compatible Storage of Waste from Human Settlements and on Biological Waste-Treatment Facilities (Abfallablagerungsverordnung - AbfAblV)
ABL	Old German Länder
AGEB	Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen)
AK	Working group (Arbeitskreis)
ALH	all other deciduous trees with high life expectancies (Tree-species group as defined within the Federal Forest Inventory (BWI))
ALN	all other deciduous trees with low life expectancies (Tree-species group as defined within the BWI)
ANCAT	Abatement of Nuisances from Civil Air Transport
AR	Activity rate
AWMS	Animal Waste Management System
B_0	Maximal CH_4-production capacity
BAFA	Federal Office of Economics and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle)
BAT	Best Available Technique
BDZ	Federal Association of the German Cement Industry (Bundesverband der Deutschen Zementindustrie)
BEF	Biomass expansion factors
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 Natural Resources (Bundesanstalt für Geowissenschaften und Rohstoffe)
BGW	Federal Association of the German Gas and Water Industry (Bundesverband der deutschen Gas- and Wasserwirtschaft)
BHD	Breast-height diameter: tree-trunk diameter at a height of 1.30 m above the ground
BImSchV	Statutory Ordinance under the Federal Immission Control Act
BML	see BMVEL
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BMELV	Federal Ministry of Food, Agriculture and Consumer Protection
BMVEL	see BMELV
BMVG	Federal Ministry of Defence
BMWi	Federal Ministry of Economics and Technology
BMWA	see BMWi
BOHE	Main survey on soil use (Bodennutzungshaupterhebung)
BREF	BAT (Best Available Technique) Reference Documents
BSB	Biological oxygen demand (BOD)
BV Kalk	German Lime Association (Bundesverband der Deutschen Kalkindustrie)
BWI	Bundeswaldinventur (Federal Forest Inventory)

BZE	Survey of soil condition (Bodenzustandserhebung)
C_2F_6	Hexafluoroethane
CAPIEL	Coordinating Committee for the Associations of Manufacturers of Industrial Electrical Switchgear and Controlgear in the European Union
CFC	Chlorofluorocarbons (= Fluorchlorkohlenwasserstoffe (FCKW))
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)
D7	Tree-trunk diameter at a height of 7 m above the ground
DESTATIS	Federal Statistical Office (Statistisches Bundesamt Deutschland)
DFIU	Franco-German Institute for Environmental Research, at the University of Karlsruhe
DG	Landfill gas
DGMK	German Scientific Society for Petroleum, Natural Gas and Coal (Deutsche Wissenschaftliche Gesellschaft für Erdöl, Erdgas und Kohle e.V.)
DIN	Deutsche Industrienorm (DIN standard)
DIW	German Institute for Economic Research (Deutsches Institut für Wirtschaftsforschung)
DLR	German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt)
DMKW	Diesel-engine power stations
D_N	N in wastewater
DOC	Degradable organic carbon
DOC_F	Fraction of DOC dissimilated
DTKW	Steam-turbine power stations
DVGW	German Association of Gas and Water Professionals (Deutsche Vereinigung des Gas- und Wasserfachs e.V.)
EBZ	Line-number in the BEU
EEA	European Environment Agency
EECA	European Electronic Component Manufacturers Association
EF	Emission factor
EI	Emissions index = Emission factor
E_{KA}	Einwohner mit Kläranlagenanschluss (Inhabitants connected to wastewater-treatment systems)
EL	Extra light (heating oil)
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)

ESIA	European Semiconductor Industry Association
EU	European Union
EUROCONTROL	European Organisation for the Safety of Air Navigation
EUROSTAT	Statistical Office of the European Communities
EW	Population equivalents (Einwohnerzahl)
FA	Combustion systems
FAL	Federal Agricultural Research Institute
FAP	coordinating expert (german: Fachlicher Ansprechpartner), assigned to organize the work in specific source categories
FAO	Food and Agriculture Organisation
FCKW	Chlorofluorocarbons (CFCs; Fluorchlorkohlenwasserstoffe)
F gases	Fluorinated hydrocarbons
FHW	District heating stations
FKW	Perfluorocarbons (PFCs; Fluorkohlenwasserstoffe)
FKZ	Research index (Forschungskennziffer)
FV	relevant expert (german: Fachverantwortlicher), assigned to cover specific source categories
FWL	Thermal output from combustion (Feuerungswärmeleistung)
GAS-EM	GASeous EMissions – A calculation programme for emissions from agriculture
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)
GMKW	Gas-engine power stations
GPG	Good Practice Guidance
GT	Gas turbines
GTKW	Gas-turbine power stations
GuD	Gas and steam turbine power stations
GWP	Global Warming Potential
HFC	Hydrofluorocarbons (german: Wasserstoffhaltige Fluorkohlenwasserstoffe (HFKW))
HFCKW	Hydrochlorofluorocarbons (HCFCs; german: Wasserstoffhaltige Fluorchlorkohlenwasserstoffe)
HFC	Hydrofluorocarbons (= HFCs; german: Wasserstoffhaltige Fluorkohlenwasserstoffe)
HQG	used synonymously to Key Category
HS-GIS	High-voltage and gas-insulated switching systems
IAI	International Aluminium Institute
ICAO	International Civil Aviation Organisation
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
IMA	Interministerial Working Group (Interministerielle Arbeitsgruppe)
IPCC	Intergovernmental Panel On Climate Change
K	Fuel input for power generation (direct drive)
k.A.	keine Angabe (no entry)
KP	Kyoto Protocol
KS	Sewage sludge
l	Level (used in the level assessment pursuant to IPCC Good Practice Guidance)
LF	agriculturally used land (german: Landwirtschaftlich genutzten 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 (german: Mechanisch-Biologische Abfallbehandlung)
MCF	Methane conversion factor
MFC	Factor for quality of landfill-gas management (methane correction factor)
MS	Medium voltage
MSW	Amount of municipal waste stored
MVA	Waste incineration plant
MW	Megawatt
N_2O	Nitrous oxide (laughing gas)
NA	Not applicable
NASA	National Aeronautics and Space Administration
NaSE	National System of Emissions Inventories
NBL	New German Länder
NE	Not estimated
NEAT	Non-energy Emission Accounting Tables
NEC Directive	Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain air pollutants
NEV	Non-energy-related consumption
NFR	Nomenclature for Reporting (new format for reporting to UN ECE)
NFZ	Utility vehicles
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 (german: Polycyclische aromatische Kohlenwasserstoffe (PAK))
PAK	see PAH

PARTEMIS	Measurement and prediction of emissions of aerosols and gaseous precursors from gas turbine engines
PCCD/F	Polychlorinated dibenzo-dioxins/- furans
PF	Process furnaces
PFC	Perfluorocarbons
PKW	Automobile (Personenkraftwagen)
PU	Polyurethane
QK	Quality control (QC)
QS	Quality assurance (QA)
QSE	Quality System for Emissions Inventories
REA	flue gas desulphurising plant (german: Rauchgasentschwefelungsanlage)
ROE	oil equivalent (german: Rohöleinheiten)
RSt	Raw steel
RWI	Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI)
S	Fuel input for power generation
S	Heavy (german: schwer), describing types of heating oil
S&A report	Synthesis and Assessment Report
SA	Heavy (german: schwer), low in sulphur (german: schwefelarm), describing types of heating oil
SF_6	Sulphur hexafluoride
SKE	Hard-coal units (Steinkohleneinheiten)
SNAP	Selected Nomenclature for Air Pollution
SO_2	Sulphur dioxide
STEAG	STEAG stock corporation: large electricity producer in Germany
t	Trend (used in the level assessment pursuant to IPCC Good Practice Guidance)
TA Luft	Technical instructions on air quality control; First General Administrative Provision on the Federal Immission Control Act
TAN	Total Ammoniacal Nitrogen
THG	Greenhouse gases (Treibhausgase = GHG)
TM	Dry mass (Trockenmasse)
TOC	Total Organic Carbon
TREMOD	Traffic Emission Estimation Model
TÜV	Technischer Überwachungs-Verein (Certifying body for technical and product safety)
UBA	Federal Environmental 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)
VDEW	Electricity Industry Association (Verband der Elektrizitätswirtschaft e.V.)
VDI	Association of German Engineers (Verein Deutscher Ingenieure e.V.)
VDN	Association of network operators (Verband der Netzbetreiber)
VDZ	German Cement Works Association (Verein Deutscher Zementwerke e.V.)
VfmD	Solid cubic meters of standing timber (Vorratsfestmeter Derbholz)

VGB	Technical association of operators of large power stations (Technische Vereinigung der Großkraftwerksbetreiber e.V.)
VIK	Verband der Industriellen Energie- and Kraftwirtschaft e.V. (VIK) (Association of the Energy and Power Industry), Essen
VOC	Volatile Organic Compounds
W	Fuel input for heat generation
WS	WS = Portion of a specific waste water treatment system (e.g. aerobic, anaerobic)
XPS	Extruded polystyrene
ZSE	Central System of Emissions (CSE)

Units etc.

Multiplication factors, abbreviations, prefixes and symbols

Multiplication factor	Abbreviation	Prefix	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
0,000.001	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

Unit	is equivalent to
1 tonne (t)	1 megagram (Mg)
1 kilotonne (kt)	1 gigagram (Gg)
1 megatonne (Mt)	1 teragram (Tg)

Explanation of the Introductory Information Tables

The Introductory Information Tables are located at the start of every source category chapter. They provide a quick roundup focusing on the relevance of the source category and the applied methods.

CRF 1.x.1.x (Sample Table)					
key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
Solid Fuels	l / t	CO_2	26,03 %	30,25 %	rising
Gaseous Fuels	l / t	CO_2	1,38 %	2,34 %	rising
Liquid Fuels	l / t	CO_2	0,64 %	0,41 %	falling
Solid Fuels	l / -	N_2O	0,25 %	0,15 %	falling

Gas	CO_2	CH_4	HFC	PFC	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)	CS	CS	NO	NO	NO	CS	CS	CS	CS	CS
EF uncertainties in %	< 3	+/-50	-	-	-	+/-50				
Distribution of uncertainties	T	U	-	-	-	U				
Method of EF determination	CS	Tier 2	-	-	-	Tier 2				

Key Category

The upper part of the table presents relevant lines from the key category analysis for individual fuel categories and gases, including the contribution to the total emissions in percent for the year 1990 and the last reported year. Emission source and sink are included.

Gas

The lower part of the table consists of the informations regarding the used emission factors, their uncertainty in percent, their distribution and the applied methods for emission factor determination.

Emission Factor (EF)

D = IPCC Default
C = Corinair
CS = Country specific
PS = Plant specific
M = Model

EF uncertainty in percent / distribution of uncertainties

see Chapter 1.7 and 18 for more details.
N = Normal
L = Lognormal
T = Triangular
U = Uniform (Gleichverteilung)

Method EF determination

D = IPCC Default
RA = Reference Approach
T1 = IPPC tier 1
T1a/ T1b/ T1c = IPPC tier 1a/ 1b/ 1c
T2 = IPPC tier 2
T3 = IPPC tier 3
C = CORINAIR
CS = Country specific
M = Model

0 SUMMARY

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 inventories of greenhouse-gas emissions. In February 2005, the Kyoto Protocol entered into force, thereby imposing additional, more extensive obligations with regard to the creation and review of emissions inventories and to emissions reporting. As a result of Europe's own implementation of the Kyoto Protocol, via the adoption of EU Decision 280/2004[1], these requirements became legally binding for Germany in spring 2004.

Inter alia, the Conference of the Parties, in adopting Decision 3/CP.5, resolved that all Parties listed in ANNEX I of the UNFCCC shall be required to prepare and submit an annual National Inventory Report (NIR) 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. The Secretariat of the Framework Convention of Climate has made submission of the inventory report a pre-requisite for performance of the agreed inventory reviews. Germany hereby submits its 2006 National Inventory Report (NIR 2006), its fourth such report together with its inventories of 2004. National greenhouse gas emission inventories for the years 1990 to 2004 have been submitted to the Secretariat of the Framework Convention on Climate. The present report also refers to that period, and it outlines the methodology and the data sources on which the calculations are based. The report and the report tables in the Common Reporting Format (CRF) have been prepared in accordance with the UNFCCC guideline on annual inventories (FCCC/SBSTA/2004/8) and, as far as possible, in accordance with the IPCC Good Practice Guidance (IPCC-GPG, 2000) and the IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry (IPCC-GPG LULUCF, 2003).

Chapter 1 describes the National System of Emissions Inventories in Germany (NaSE), which is designed to aid compliance with all reporting obligations with respect to atmospheric emissions and storage in sinks. Apart from the Kyoto Protocol requirements, the NaSe in future will also be used to meet other legal obligations (the UNECE Geneva Convention on Long-range Transboundary Air Pollution, the EU Directive on National Emission Limits) that Germany has entered into. In addition, this chapter describes the basic principles and methods with which the emissions and sinks of the IPCC categories are calculated, and it describes the Quality System of Emissions Inventories (QSE). Over the past three years, the participating institutions, via considerable efforts, have helped improve the relevant database and close gaps in the data. Efforts to systematically improve the inventory continue and are being given high priority.

Chapter 2 provides a general overview of development of emissions of greenhouse gases and their storage in sinks.

Chapters 3 to 9 contain detailed information about the main groups of emissions sources and sinks; this information is designed to enhance the transparency of calculations of German greenhouse-gas emissions and sinks.

In keeping with existing EU regulations, submitted inventories must be accompanied by determination of the inventory for the base year from which the assigned amounts for the first

[1] Decision No. 280/2004/EC of the European Parliament and the Council of 11 February 2004 on a system for monitoring greenhouse-gas emissions in the Community and for implementing the Kyoto Protocol (OJ. EU L 49 p. 1)

commitment period under the Kyoto Protocol are derived. Since these assigned amounts may no longer be changed in future, via recalculations, the emissions inventories were extensively revised over the past year. In the process, persisting gaps in the inventories were closed. As a result of this revision, the figures for achieved emissions reductions differ somewhat from those reported in previous years.

In comparison to the National Inventory Report for 2005, this year's report has been improved in the following areas:

- The quality assurance system is now being used throughout the entire emissions-reporting process,
- The transparency of recalculations has been enhanced,
- All of the energy-consumption figures on which the base year is based have been reviewed and adjusted as necessary (especially for the territory of the new German Länder),
- Emissions resulting from increasing use of substitute fuels (fractions with high net calorific values, specified waste) in industrial combustion systems have been included,
- Emissions from use of limestone and lime have been included,
- The emissions from lubricants in road traffic have been estimated,
- A more precise calculation procedure for fugitive CH_4 emissions in coal mining has been introduced,
- Fugitive CO_2 emissions from oil and gas have been included, while emissions from gas production and processing (acidic gas) have been reported for the first time,
- CO_2 emissions from the iron and steel sector have been recalculated,
- Emissions from non-energy-related fuel consumption have been included,
- The gaps in the data on coke burn-off in catalyst regeneration for refineries have been eliminated,
- The emissions from industrial combustion have been broken down in accordance with the specified industrial sectors,
- For the first time, assumptions have been made relative to emissions in the area of ferroalloys,
- The methods for calculating emissions in the areas of agricultural animal husbandry and fuel production and distribution have been changed,
- The entire area of land use / land-use changes has been defined using a new method.

As a result of international inventory review, carried out as in-country review in 2004 and as a centralised review (by the Climate Secretariat) in 2005, the experts working on behalf of the Climate Secretariat identified additional required improvements. The intensive national process of inventory improvement needs to be continued in 2006. The methodological changes being made to implement the *Good Practice Guidance* (GPG) in the inventories have not yet been completed. More detailed information about specific relevant issues is presented in the literature listed in **Chapter 11**.

General information on recalculations and improvements can be found in **Chapter 10**.

The Federal Environmental Agency makes all calculations for the greenhouse-gas inventory and carries out all relevant compilation. Emissions and sinks from agriculture, changes in land use and forestry were provided by the Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL) and the Federal Agricultural Research Institute (Bundesforschungsanstalt für Landwirtschaft, FAL).

0.1 Background information on greenhouse-gas inventories and climate change

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 30 % compared to their levels in pre-industrial times, whilst those of methane (CH_4) have increased by 145 % and those of nitrous oxide (N_2O) have grown by 15 %. Furthermore, a number of brand-new substances such as chlorofluorocarbons (CFCs), halons, perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF_6) have entered the atmosphere which almost never occur in nature and are generated almost exclusively by humans.

As a Party to the United Nations Framework on Climate Change, 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, thereby imposing additional, more extensive obligations with regard to the creation and review of emissions inventories and to emissions reporting.

In the framework of the Kyoto Protocol, the European Union has committed to reducing its greenhouse-gas emissions by 8% by the 2008–2012 period, in comparison to their base-year levels (1990 and 1995[2]). This commitment has been divided between the EU Member States in the framework of a burden-sharing agreement[3]. Under this agreement, Germany has agreed to reduce its emissions by 21 % in comparison to the base year and thus has agreed to make a substantial contribution to fulfillment of the EU's commitment. Consequently, Germany's relevant measures, and its calculations relative to emissions reductions, are being followed with considerable interest.

0.2 Greenhouse-gas emissions and their storage in sinks (with respect to GWP) over time: 1990-2004

By 2004, Germany reduced its emissions by 17.4 % in comparison to the base year, thereby already fulfilling much of its its commitments within the framework of European burden-sharing. The individual greenhouse gases contributed to this development to varying degrees (see Table 1). This is hardly surprising given that, in any given year the various greenhouse gases account for varying proportions of total emissions (see Table 2).

[2] For HFC, PFC and SF_6

3 burden sharing agreement, approved via Council Decision 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]

Table 1: Greenhouse-gas emissions in Germany – changes with regard to the base year[4]

Greenhouse gas emissions	Base year	1990	1995	2000	2001	2002	2003	2004
	CO_2 equivalent [Gg]							
Net CO_2 emissions / removals	1.001.615,6	1.001.615,6	888.618,2	851.904,0	864.173,3	851.131,3	856.674,9	849.601,8
CO_2 emissions (without LUCF)	1.030.231,3	1.030.231,3	920.154,9	886.258,2	899.301,0	886.480,3	892.545,2	885.854,2
CH_4	99.794,7	99.794,7	81.748,5	64.912,5	62.084,0	59.162,3	56.171,8	51.443,0
N_2O	84.783,6	84.783,6	77.683,2	59.627,2	60.352,2	59.779,9	62.433,8	64.281,5
HFC	6.555,5	4.368,8	6.555,5	6.556,1	7.971,1	8.647,0	8.486,9	8.802,0
PFC	1.749,6	2.707,6	1.749,6	785,7	723,2	794,7	857,3	830,5
SF_6	7.223,8	4.785,0	7.223,8	5.079,0	4.898,9	4.201,5	4.304,6	4.480,5
Total #	**1.201.722,8**	**1.198.055,3**	**1.063.578,8**	**988.864,5**	**1.000.202,7**	**983.716,7**	**988.929,3**	**979.439,4**
Total *	**1.230.338,5**	**1.226.671,0**	**1.095.115,6**	**1.023.218,8**	**1.035.330,4**	**1.019.065,7**	**1.024.799,5**	**1.015.691,8**

*) without CO_2 from LUCF #) without net CO_2 emissions / removals

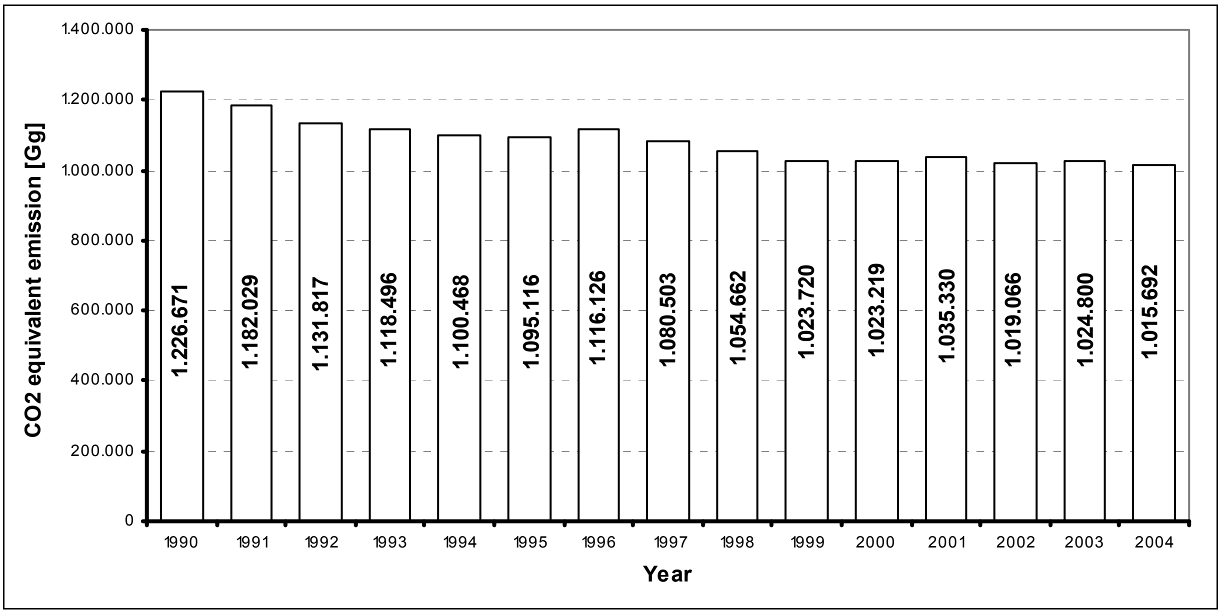


Figure 1: Overall development of greenhouse gases in Germany, in CO_2 equivalents (without CO_2 from LUCF)

4 Base year 1990 for CO_2, CH_4, N_2O; 1995 for HFC, PFC, SF_6

Table 2: Greenhouse-gas emissions in Germany – annual contributions of the various greenhouse gases

Greenhouse gas emissions [CO_2-Eqivalent]	Base year		1990		1995		2000		2004	
	[Gg]	[%]	[Gg]	[%]	[Gg.]	[%]	[Gg]	[%]	[Gg]	[%]
CO_2 emissions *	**1.030.231**	83,7	**1.030.231**	84,0	**920.155**	84,0	**886.258**	86,6	**885.854**	87,2
CH_4	**99.795**	8,1	**99.795**	8,1	**81.749**	7,5	**64.912**	6,3	**51.443**	5,1
N_2O	**84.784**	6,9	**84.784**	6,9	**77.683**	7,1	**59.627**	5,8	**64.281**	6,3
HFC	**6.555**	0,5	**4.369**	0,4	**6.555**	0,6	**6.556**	0,6	**8.802**	0,9
PFC	**1.750**	0,1	**2.708**	0,2	**1.750**	0,2	**786**	0,1	**831**	0,1
SF_6	**7.224**	0,6	**4.785**	0,4	**7.224**	0,7	**5.079**	0,5	**4.480**	0,4
Total *	**1.230.338**		**1.226.671**		**1.095.116**		**1.023.219**		**1.015.692**	

*) without CO_2 from LUCF

In 2004, releases of carbon dioxide from stationary and mobile combustion processes was the main source of greenhouse-gas emissions, accounting for 86.9 % of all such emissions. As a result of a disproportionately large reduction of other greenhouse-gas emissions, CO_2 emissions' share of total emissions has increased by 3.5 percentage points since the base year. Methane (CH_4) emissions from animal husbandry, fuel distribution and landfills account for 5.0 %. Emissions of nitrous oxide (N_2O), caused primarily by agriculture, industrial processes and transport, contribute 6.3 % of greenhouse-gas releases. Fluorocarbons (so-called "F gases") account for about 1.4 % of total emissions. The distribution of Germany's greenhouse-gas emissions is typical for a highly developed and industrialised country.

Emissions are calculated component-specifically for the source groups and sinks defined by the IPCC. The greenhouse-gas inventories do not take account of chemical reactions, in the atmosphere, of C-containing compounds (such as NMVOC solvents) not emitted as CO_2.

0.3 Overview of emissions estimates and trends for source and sink categories

Figure 2 shows the contributions of individual source and sink categories to total greenhouse-gas emissions. It highlights the relative constancy of the shares of the various source and sink categories and the absolute dominance of energy-related emissions. In fact, these have continuously decreased over time. The slight re-increases in 1996, 2001, and 2003 are temperature-related. These years had lower winter temperatures, leading to intensified energy consumption for indoor heating and, thereby, to higher emissions. This is documented by independently calculated temperature corrections for energy-related CO_2 emissions (ZIESING, 2004: Table. 5).

Overall, greenhouse-gas emissions have decreased considerably since 1990 (decrease of CO_2-equivalent emissions by 17.4 %). Considerations of the various components involved confirm this trend, to varying degrees. For example, the emissions changes since base-year 1990 for the most important greenhouse gases by amount are as follows: -14 % for carbon dioxide (CO_2), -48.5 % for methane (CH_4) and – 26.3 % for nitrous oxide / laughing gas (N_2O). The corresponding trends for the so-called "F" gases, which contribute about 1.4 % 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 38.0 % and PFC emissions dropped by 52.5 % (CF_4 -66.0 %; C_2F_6 -31.3; bei C_3F_8 +1561.0 %), while HFC emissions increased by 34.3 %.

In comparison to the previous year, 2003, total emissions decreased by nearly 1 % (- 0.9 %). This is due, in large measure, to a 5 % drop in CO_2 emissions from households and small consumers (indoor heating), resulting from decreased energy consumption, as well as to a 20 % decrease in CH_4 emissions from coal mining, resulting from considerably increased use of pit gas.

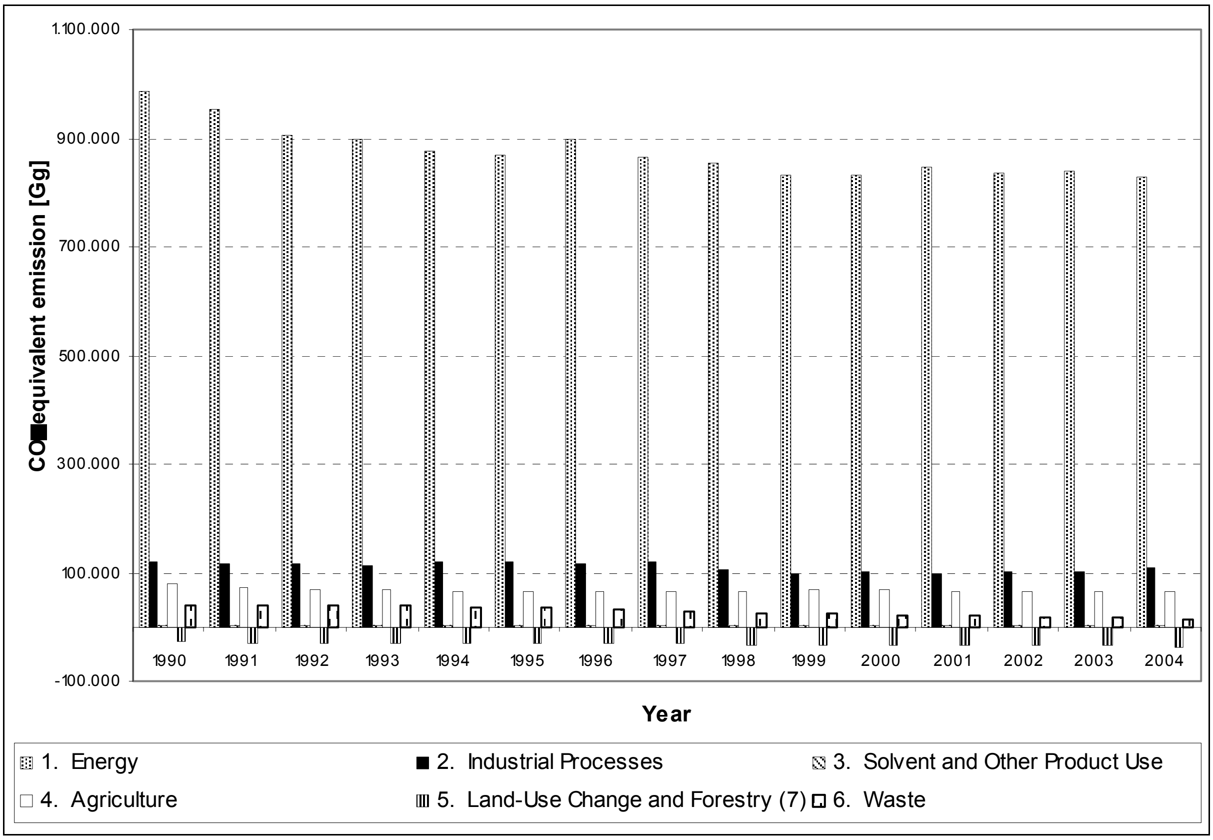


Figure 2: Greenhouse-gas emissions trends, by source groups, in CO_2 equivalents[5]

Figure 3 shows the relative developments of emissions from polluter 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 reduction in the quantity of waste that is landfilled and hence to a reduction in landfill emissions. In the area of emissions from industrial processes, the emission-reducing effects of measures in the field of adipic acid production in 1997 were substantial. Emissions from solvent and other product use decreased slightly, as a result of decreased narcotic use of N_2O.

The trend in emissions from agriculture essentially follows the development of livestock figures.

[5] CO_2 emissions and storage in soils are reported under land-use changes and forestry.

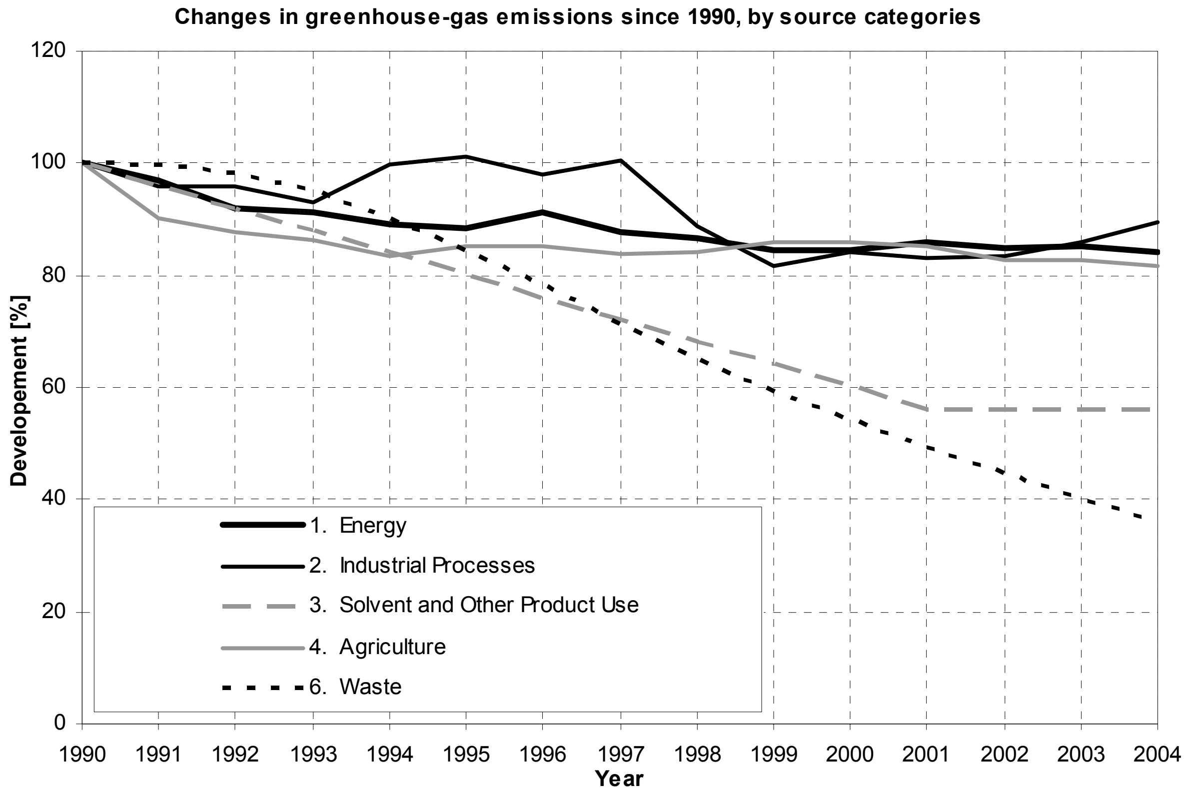


Figure 3: Relative development of greenhouse-gas emissions since 1990, by source categories[6,7]

[6] CO_2 emissions and storage in soils are reported under land-use changes and forestry.
[7] The percentages refer to the emissions of the year 1990 (=100%), not to those of the base year.

1 INTRODUCTION

1.1 Background information on climate change and on greenhouse-gas inventories

1.1.1 The greenhouse effect

Climate change consists of changes in average weather conditions over an extended period of time; it can occur in a particular area or be global. Paleo-climate research has shown that major climate changes, with fluctuations of the global mean temperature ranging from 9°C to 16°C, have occurred naturally in the past millions of years. Climate change may be attributable to the following causes:

- Changes in so-called "geo-astrophysical parameters" such as solar constant, elements of the earth's orbit, etc.
- Changes in the earth's surface
- Changes in the energy balance in the system of the "*earth's surface and atmosphere*"
- 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 water vapour (the most important natural greenhouse gas), have a particular property. They allow the energy-rich radiation falling onto 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. In simplified terms, this is the nature of the greenhouse effect.

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

1.1.2 Climate change

Ever since the start of industrialisation, significant supra-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 30 % compared with the levels in pre-industrial times, whilst those of methane (CH_4) have increased by 145 % and those of nitrous oxide (N_2O) by 15 %. Furthermore, a number of brand-new substances such as chlorofluorocarbons (CFCs), halons, perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF_6) have entered the atmosphere which almost never occur in nature and are generated almost exclusively by humans.

Although the triggers of the greenhouse effect are minimal in volume terms, their effects are substantial. The increase in the concentration of greenhouse gases serves to reinforce the (natural) greenhouse effect and hence leads to an increase in ground-level temperature. The natural greenhouse effect is essential to life; however, its reinforcement as a result of human intervention is cause for concern. The change in one climate factor in the composition of the atmosphere may lead to far-reaching and rapid changes in the entire climate system via multiple interactions. Because ecosystems and civilisation itself are adapted to the current climate conditions, such changes may have threatening consequences.

In its most recent report of 2001, the IPCC (Intergovernmental Panel on Climate Change) ascertained, *inter alia*, that the average global air temperature has increased by between 0.4 and 0.8°C over the past 100 years. The past few years have been among the warmest since 1861 (beginning of regular record-keeping in Germany).

1.1.3 Reduction obligations and reporting of greenhouse gases

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 on Climate. 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 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. Pursuant to the Kyoto Protocol, industrialised nations must 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 by 2012. The U.S. and Australia have not ratified the Kyoto Protocol. In the framework of the Kyoto Protocol, the European Union has committed to reducing its greenhouse-gas emissions by 8% by the 2008–2012 period, in comparison to their base-year levels. Within the EU, this commitment has been divided up between the Member States via a burden-sharing arrangement[8] whereby Germany is called on to make a substantial contribution of a 21 % emissions reduction in comparison to the base year. Consequently, Germany's relevant measures, and its calculations relative to emissions reductions, are being followed with considerable interest.

The effectiveness and success of the Kyoto Protocol vis-à-vis reduction of global greenhouse gas emissions will 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 is reliable. As such, national reporting and the subsequent international review of emissions inventories play a key role.

8 Burden-sharing agreement; adopted via Council decision 2002/358/EC

1.2 Institutional specifications and framework conditions for inventory preparation

In Germany, emissions reporting is co-ordinated by the Federal Environmental Agency. Since the mid-1990s, when reporting obligations for preparation of emissions inventories of air pollutants and climate gases increased sharply, efforts to harmonise emissions calculation and reporting have been intensified. At the same time, requirements from reporting obligations relative to the UN ECE Geneva Convention on Long-range Transboundary Air Pollution and its protocols, and to the EU NEC Directive, are being taken into account. The provisions of the Kyoto Protocol have led to a fundamental review and reorientation of German emissions reporting. Since 2002, the Federal Environmental Agency has been carrying out this task energetically.

All reporting obligations require that the Parties carry out transparent, comparable, complete, consistent and precise emissions calculations. In particular, as a result of integration of flexible instruments within the Kyoto Protocol, specific requirements for implementation of the aforementioned aims are in place. Introduction of Joint Implementation, Clean Development Mechanisms and emissions trading will ultimately give emissions monetary value, with the result that a number of procedures will be required to make the Protocol's provisions enter into force and to deal with issues of monitoring and control of compliance. Only when independent review of a Party's inventories has been completed, with no objections raised, can the state be certified for use of flexible instruments (cf. Figure 4).

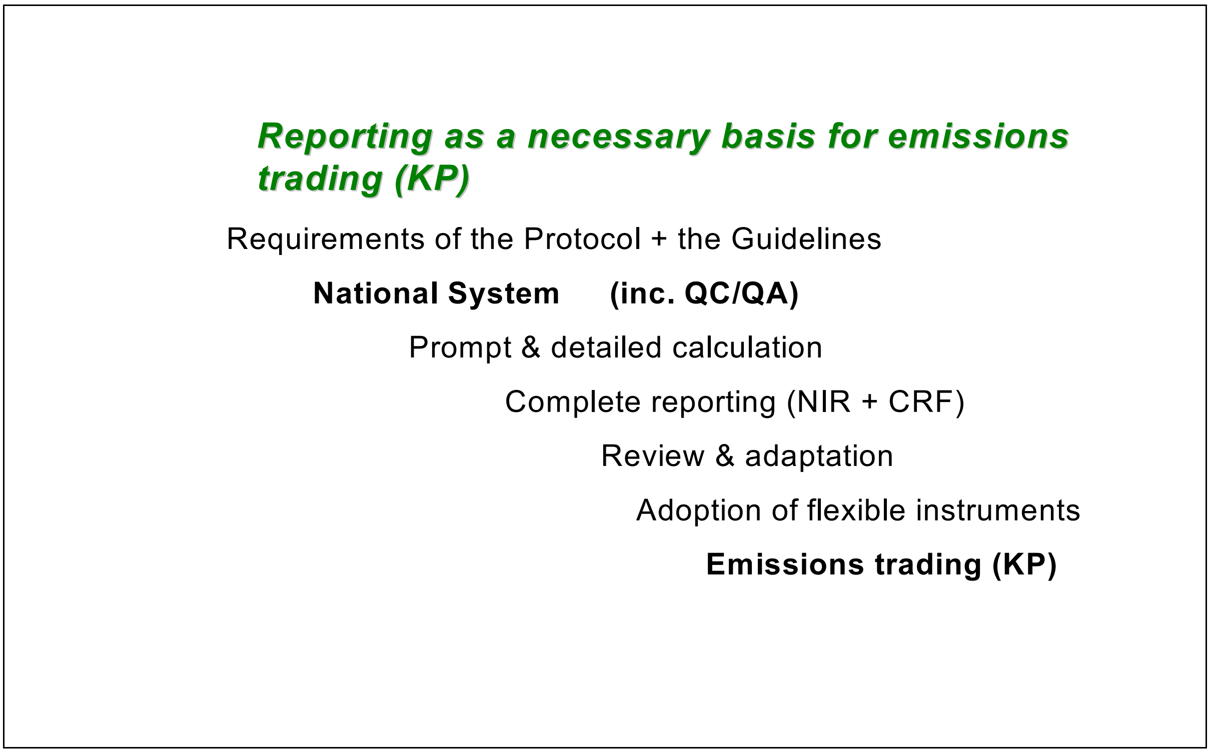


Figure 4: Pre-requisites for the use of the KP's flexible instruments

The requirements are not limited to preparation of inventories; they also comprise the entire relevant process, from data collection to reporting. Quality management plays a particularly important role. In order to create a defined framework for the process of greenhouse-gas reporting, the Member States are obligated to establish national systems, for inventory preparation, that permit continual inventory improvement.

In 2002, Germany began taking the necessary steps for establishment of a National System of Emissions Inventories. It is designed to function as a network of all federal and Länder organisations, research institutes, associations and other organisations that can help improve the inventory calculations. Another focus of initial work is to institutionalise the National System in Germany. Such institutionalisation must ensure that the system can function effectively, with little red tape and with binding, sufficiently reliable procedures (for further information about the National System, see Chapter 17.1).

1.2.1 Institutional specifications for inventory preparation

In 2005, decisive progress was made in institutionalising the National System. Via in-house order (Hausanordnung 11/2005), the Federal Environmental Agency (UBA) has issued binding provisions on competencies, a list of deadlines for the various inventory-preparation steps and the necessary relevant checking for purposes of quality control / quality assurance.

At the same time, the necessary basis for integration of other German authorities within the National System and for interministerial cooperation remains to be created. In addition, non-government-authority players are not yet being integrated systematically within the National System.

At present, the following institutional links and specifications apply to inventory preparation in Germany:

1. The *co-ordinating office of the National System* – the "Single National Entity" (SNE) – is housed within Section I 4.6 of the Federal Environmental Agency. This is specified in the Federal Environmental Agency's in-house order (Hausanordnung) 11/2005, and it is to be similarly specified in the planned Act on climate-protection statistics (KSStatG).
2. A *Working Group on Emissions Inventories* is in place to co-ordinate relevant work within the Federal Environmental Agency; it will incorporate all of the agency's employees who are involved in inventory preparation.
3. A *Working Group VI (Emissions Reporting)*, founded in 2002 within the CO_2 Reduction Interministerial Working Group[9], is charged with implementing emissions-reporting requirements within federal agencies. Interministerial discussion on central tasks in emissions inventories, as identified to date, is being carried out in this framework. Co-ordination is being carried out by the BMU. Planning calls for the working group to meet three times per year.
4. The *framework departmental agreement between the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) and the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety (BMU)* regarding data and information exchange and the operation of a joint database on emissions from agriculture, dated 2 April 2001, marked the first-ever inter-departmental agreement on co-operation in calculation of emissions.
5. The BMELV and the Federal Agricultural Research Institute (FAL) are providing the Federal Environmental Agency with the inventory data on agriculture and forestry.
6. At present, the involvement of the Federal *Länder* is being ensured via the *Länder Committee on Immission Protection* (LAI). This is required in particular for validation of the Energy Balance of the Federal Republic of Germany with the energy balances of

9 Following a resolution by the Federal Government on 13 June 1990, the IMA on CO_2 Reduction was founded under the auspices of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). The aim is to further develop and implement an overall concept for CO_2 reduction and global warming prevention at the national level.

the *Länder*, as well as for the process for verification of Federal and *Länder* emissions inventories. In the area of energy, intensive co-operation is also taking place with the Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen - AGEB) and with the German Institute for Economic Research (DIW), which prepares the Energy Balance of the Federal Republic of Germany under commission to the AGEB.

7. *Involvement of associations* and other independent organisations has been achieved primarily via the sections of divisions I and III, at the Federal Environmental Agency, responsible for concrete issues. The *Single National Entity* supports the specialist departments in discussion of reporting requirements and in determination of requirements for data-sharing by associations. At the end of 2004, the first workshop on the National System was held; such workshops provide a forum that significantly facilitates integration of associations and other independent organisations.
8. Inventory preparation has always made use of the expertise of *research institutions*, via execution of research and development projects in the UFOPLAN (environmental research plan) framework. This occurs via work on specific issues, and it takes place via overarching projects, which primarily support harmonisation of individual results, for the overall inventory, as well as identification of gaps in lists of emission-relevant activities. Since UFOPLAN 2002, the Single National Entity has had a global project *on updating emissions-calculation methods*, a project within which it can initiate measures for continuous inventory improvement. Individual measures for improving inventories are initiated and financed via establishment of sub-projects.
9. The average length of time required for commissioning via the UFOPLAN, from problem identification (project initiation) to solution (acceptance of the final report), is 3.5 years. Since inventories must be reviewed annually by independent experts of the Climate Secretariat, and since improvements relative to deficiency reports must be initiated promptly, the response time for eliminating priority deficiencies must be one year, however. For this reason, a separate budget position for the National System, over and above research funding, has been established within the Federal Environmental Agency as of 2005 (Title 526 02, Chapter 1605, No. 4.15). This position can be used to fund short-term projects for inventory improvement, within the Agency's responsibility.

1.2.2 Framework conditions for inventory preparation

Inventory preparation necessitates extensive preliminary work from the specialist departments of the Federal Environmental Agency and other institutions. Since 2003, the Single National Entity has been working, by providing suitable specifications for inventory preparation and quality assurance, to create a standardised framework for the various relevant players.

The framework conditions for inventory preparation in Germany are currently as follows:

1. In 2005, via its in-house order (Hausanordnung) 11/2005, the Federal Environmental Agency established a Quality System for Emissions Inventories (QSE) that will provide the necessary framework for compliance with good inventory practice and for execution of routine quality assurance. This system is structured in accordance with the requirements of the *IPCC Good Practice Guidance*, and it has been adapted to national circumstances in Germany and to the internal structures and procedures of the Federal Environmental Agency, the reporting institution. Within the QSE framework, binding specifications were issued regarding the procedural organisation

for emissions reporting, relevant competencies and the necessary QC and QA measures. At the same time, the necessary basis for integration of other German authorities within quality assurance for the National System remains to be created. The Quality System of Emissions Inventories, which is currently under development, is described in greater detail in Annex 6 (Chapter 17).

2. The database of the Federal Environmental Agency's *Central System on Emissions* (CSE) is used for central storage of all information required for emissions calculation (methods, activity rates, emission factors). The CSE is the main instrument for documentation and quality assurance at the data level. A more detailed description of the CSE is provided in Annex 6.
3. A binding schedule for preparation of emissions inventories and of the NIR is announced to all relevant internal and external players via the Federal Environmental Agency's Website and via publication within the NIR itself. In 2005, and for all subsequent years, the following schedule holds for inventory data (all pollutants) and for the pertinent descriptions in the National Inventory Report (initially, covering only GHG):

05. May	The Federal Environmental Agency's national co-ordinating agency (Single National Entity) requests relevant responsible sections to submit data and report texts
01. September	Deliveries from Federal Environmental Agency and from external institutions of the NaSE
02. September	Validation / discussion of deliveries by section and quality managers, taking account of review results
September - October	Inventory review by the Climate Secretariat
01. October	Preparation of CRF time series; final editing by the Single National Entity within the Federal Environmental Agency
01. November	Internal co-ordination within the Federal Environmental Agency
15. November	Final quality assurance by the QSE/ZSE/NIR coordinator
30. November	Report of the Single National Entity to the Ministry, for commencement of inter-ministerial coordination
15. January	Report to the European Commission (within the framework of the CO_2-monitoring mechanism)
15. April	Report to the Secretariat of the FCCC
May	Initial check by the FCCC Secretariat
June	Synthesis and assessment report I (by the UN Climate Secretariat)
August	Synthesis and assessment report II (country-specific; by the UN Climate Secretariat)

1.3 Short description of inventory preparation

Inventory preparation is managed by the *Single National Entity* (Section I 4.6 of the Federal Environmental Agency). The process of inventory preparation is coordinated closely with preparation of the National Inventory Report and with execution of quality assurance procedures.

Emissions reporting is a process that is carried out regularly, on a yearly basis. Apart from routine, ongoing sub-processes such as data collection, data preparation, emissions calculation and report preparation, definition of the bases for calculation plays a particularly important role in this overall process (cf. Figure 5). Such definition may be required at any time as a result of certain types of events (such as changes in main source categories, issue of new IPCC requirements, identification of deficits pursuant to the inventory plan, identification of potential for improvement, etc.). On an annual basis, in connection with the other routine sub-processes, it is determined whether such events have occurred. Suitable QC measures are assigned to each step of the process. Since 2005, the proper execution of such measures is recorded in QC checklists, by the relevant experts (to date, only for Tier 1).

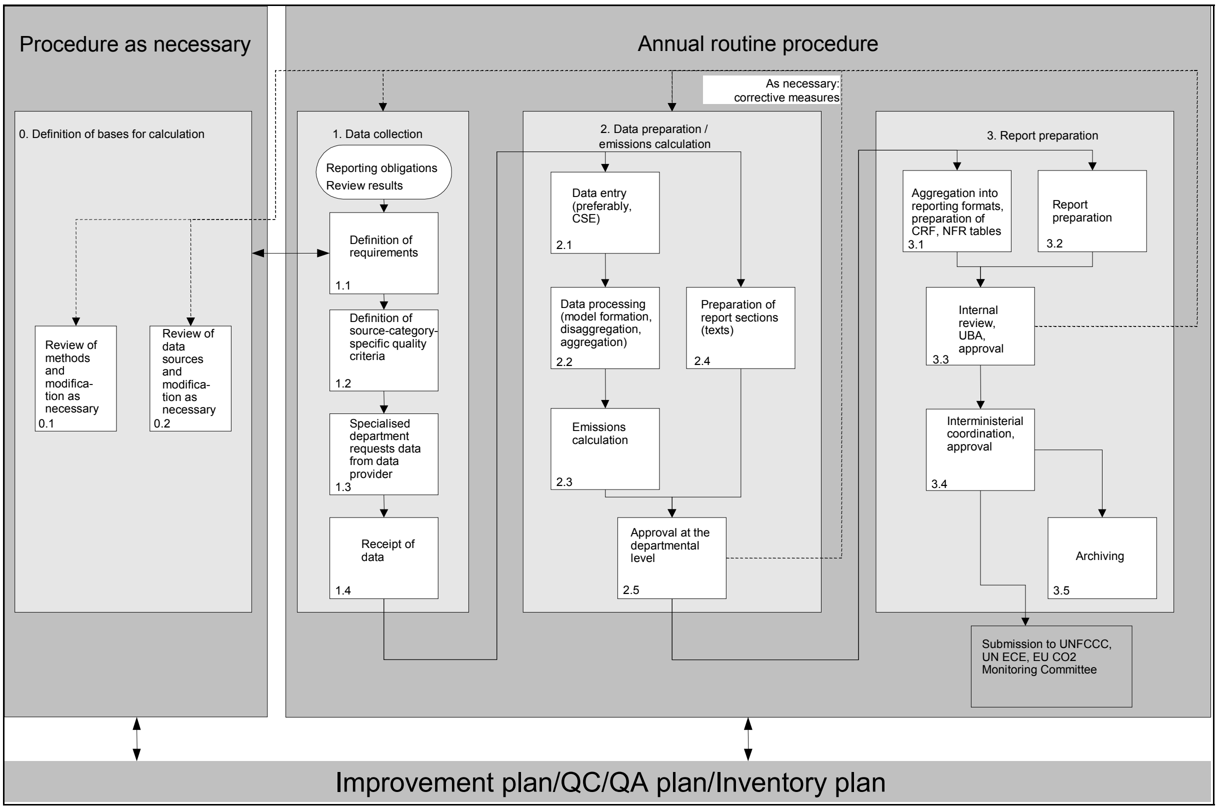


Figure 5: Overview of the emissions-reporting process

1.3.1 *Definition of bases for calculation*

Selection of calculation methods for determining emissions affects the entire emissions-reporting process. For this reason, the overall process must begin with review of the suitability of the methods to be used. *IPCC Good Practice Guidance* specifies, via use of decision trees, what methods are to be used for the various source 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 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 rates, emission factors or emissions for/of a specific source 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.

Data-source selection must be oriented to these criteria. On the other hand, in each case, selection of a specific data source must be made on a case-specific basis, by the parties responsible for the subject area in question. In practice, where a choice between use of poorly documented data or no data at all presents itself, use of the poorly documented data must always be considered. 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 Environmental Agency, as the customer for such services, must be able to influence such projects.

1.3.2 Data collection

Data collection and documentation take place under the responsibility of the relevant experts. An organisation may collect data by evaluating official statistics or statistics from associations, studies, periodicals or external research projects, by conducting its own research projects, by obtaining information from relevant persons, or by accessing data exchanges between the Federal Government and the *Länder*. 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,
- Specification of the source-category-specific quality and review 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) requests inventory input from the experts responsible for the source category in question, via the experts' superiors. In future, this will occur within the framework of an inventory plan. 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 source categories and the current results of key category identification, are all communicated to the relevant experts via informational events held by the Federal Environmental Agency's *working group on emissions inventories*, and via the Federal Environmental Agency's intranet site for emissions reporting. On this basis, responsible experts **define requirements** for relevant third parties, with regard to both data sources and 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 source-category-specific quality and review 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 is checked for completeness, compliance with quality criteria and currentness. Data validation is carried out by the relevant expert.

1.3.3 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 texts, and
- Approval by the relevant experts.

Report texts are prepared along with the time series – which enter into the table sections – for activity rates, 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.

Considerable amounts of **data entry and processing** (processing of data, and emissions calculation oriented tightly to the data) take place in the CSE. This considerably enhances transparency and consistency, and it opens up the possibility of automating data-level quality-control measures in the CSE (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. 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 rate * 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.

1.3.4 Report preparation

Report preparation includes the following steps:

- Aggregation of emissions data into the relevant report formats, and preparation of data tables (CRF, NFR),
- Calculation of CO_2 equivalents for the greenhouse-gas emissions,
- Compilation of submitted report texts to form a report draft (NIR), and editing of the complete NIR,
- Review of the draft by the Federal Environmental Agency, followed by approval as appropriate,
- Forwarding to the BMU,
- Inter-ministerial co-ordination, followed by
- Handover to the UNFCCC Secretariat and
- Archiving.

Before emissions data can be transferred into the report tables for the Framework Convention on Climate Change (CRF = Common reporting Format) and for 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 source-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. Aggregations are carried out automatically.

Following mathematical aggregation, activity data, emission factors and emissions are automatically entered into the IPCC's CRF report tables. In future, the CRF reporter will be supplied from the CSE, via a suitable interface.

At present, all emissions data not included in the CSE is still entered manually into the CRF tables. This process involves an increased risk of error, and thus report tables must be cross-checked by an independent reviewer.

Mathematical conversion of greenhouse gases into CO_2 equivalents takes place pursuant to Art. 20 of the *IPCC Guidelines on Reporting and Review* (FCCC/CP/2002/8), on the basis of the GWP published in the *Second Assessment Report* and listed in Table 3.

Table 3: 1995 IPCC GWP values based on the effects of greenhouse gases over a 100-year time horizon

Greenhouse gas	Chemical formula	1995 IPCC GWP
Carbon dioxide	CO_2	1
Methane	CH_4	21
Nitrous oxide	N_2O	310
Hydrofluorocarbons (HFC)		
HFC-23	CHF_3	11700
HFC-32	CH_2F_2	650
HFC-41	CH_3F	150
HFC-43-10mee	$C_5H_2F_{10}$	1300
HFC-125	C_2HF_5	2800
HFC-134	$C_2H_2F_4$ (CHF_2CHF_2)	1000
HFC-134a	$C_2H_2F_4$ (CH_2FCF_3)	1300
HFC-152a	$C_2H_4F_2$ (CH_3CHF_2)	140
HFC-143	$C_2H_3F_3$ (CHF_2CH_2F)	300
HFC-143a	$C_2H_3F_3$ (CF_3CH_3)	3800
HFC-227ea	C_3HF_7	2900
HFC-236fa	$C_3H_2F_6$	6300
HFC-254ca	$C_3H_3F_5$	560
Perfluorocarbons (PFC)		
Perfluoromethane	CF_4	6500
Perfluoroethane	C_2F_6	9200
Perfluoropropane	C_3F_8	7000
Perfluorobutane	C_4F_{10}	7000
Perfluorocyclobutane	c-C_4F_8	8700
Perfluoropentane	C_5F_{12}	7500
Perfluorohexane	C_6F_{14}	7400
Sulphur hexafluoride		
Sulphur hexafluoride	SF_6	23900

Source: FCCC/CP/2002/8, p.15

The report co-ordinator **compiles the submitted report texts to form the NIR draft**. Experts in the Single National Entity (national co-ordinating agency), assigned to cover specific source categories, then carry out **internal review of the data and report sections**, 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. Following such revision, the report co-ordinator carries out overall editing of the NIR.

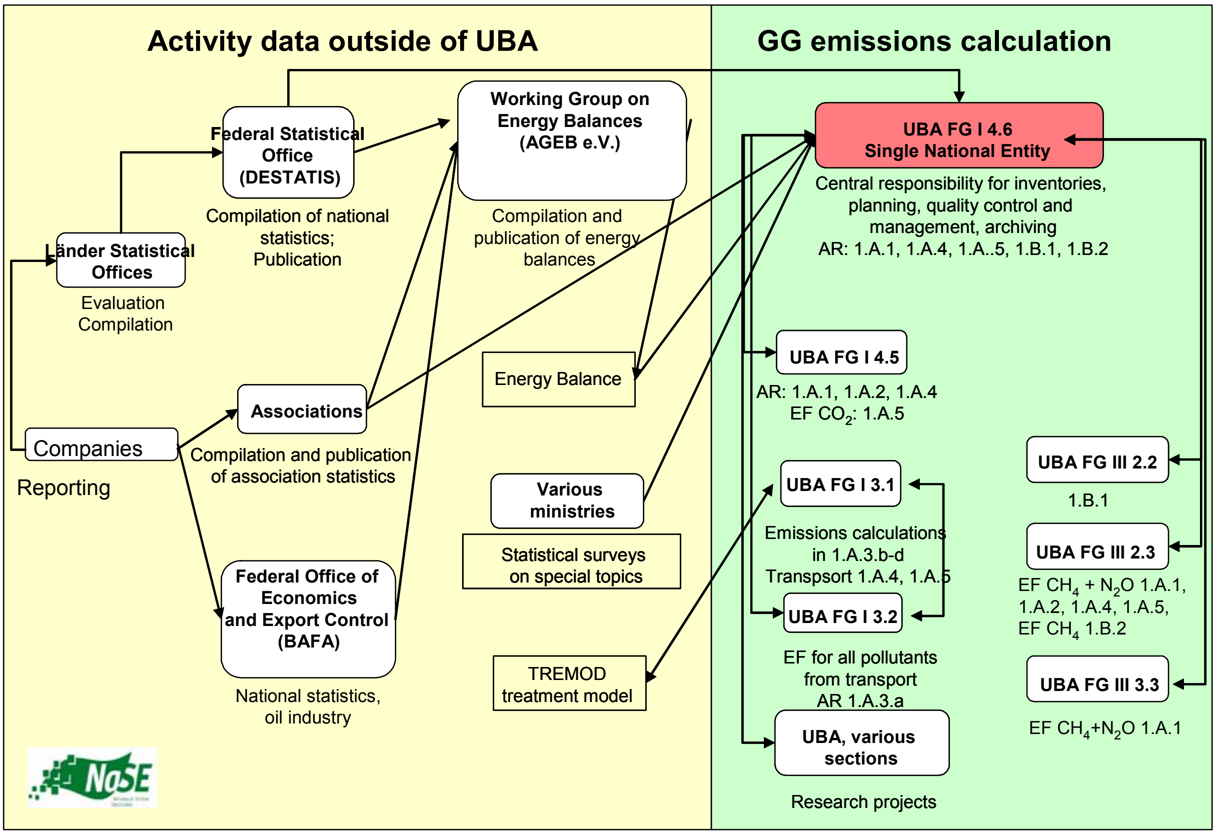
Formal approval of the report tables and the NIR, and of the inventory plan to be included in future, is provided via co-signing in the framework of the Federal Environmental Agency's internal co-ordination process. The documents are then **forwarded to the BMU** for **ministerial co-ordination**. The ministry arranges for translation of the NIR and for **its submission to the UNFCCC Secretariat**.

The data tables and the related NIR, in the version provided for ministerial co-ordination, are then transferred onto a CD and archived with clear identification information. The content of the CSE database used for calculation purposes is likewise copied and archived. The final version submitted to the Secretariat of the Framework Convention on Climate is also **archived**.

1.4 Brief general description of methodologies and data sources used

1.4.1 Data sources

1.4.1.1 Energy



Source: ÖKO-INSTITUT, 2004a, modified

Figure 6: 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 rates in the CSE are the *"Energiebilanzen der Bundesrepublik Deutschland"* (Energy Balances of the Federal Republic of Germany, hereinafter referred to as: Energy Balance), which are published by the *Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen)*. An energy balance provides an overview of the links within Germany's energy sector, and it supports breakdowns in accordance with fuels and source categories. An energy balance receives data from a wide range of other sources. As a result, publication of energy balances is subject to some delay. The most recent available Energy Balance (last revised in December 2005) describes the year 2002.

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.

Also along with the Energy Balance, the Working Group on Emissions Balances (AGEB) also publishes "Evaluation Tables for the Energy Balance" (*Auswertetabellen zur Energiebilanz* (hereinafter referred to as: Evaluation Tables). In the area of fuels, these tables only list those fuels with the highest activity levels and aggregate lower activity levels to form sum values (such as *other solid fuels*). Breakdowns according to specific source categories are limited largely to source categories that consume final energy (such as *manufacturing sector* or *transport*). Some source categories are not listed (such as *production of district heat*). The evaluation tables are published relatively promptly (in the summer of the relevant subsequent year). The tables can be used to determine aggregated activities at the source-category levels for the most commonly used fuels. Further disaggregation can be achieved via formation of relevant differences using other statistics.

At short intervals (one to two years), the Association of Industrial Energy and Power Producers (*Verband der Industriellen Energie- und Kraftwirtschaft (VIK) e.V.*) publishes Energy-Sector Statistics (*Statistik der Energiewirtschaft* (hereinafter referred to as: VIK Statistics). The VIK Statistics include data on power generation, types of facilities and fuel consumption. Their data is broken down extensively, in accordance with both source categories and types of facilities. The VIK Statistics are normally published within a little over a year after the relevant data has been collected.

Another important data source for determining activity rates in the CSE consists of the *Fachserien 4 (technical series) Reihe (series) 4.1.1, Reihe 6.4 and Reihe 8.1* (hereinafter referred to as: Fachserie 4) of the *Federal Statistical Office*. These publications contain data on production-related fuel consumption, and on facilities and plants, in the manufacturing and mining sectors. This data is published relatively promptly after collection (about one year), and it is broken down finely in accordance with various areas of the manufacturing sector. Some of this data is also included in the VIK Statistics.

Coal-industry statistics (Statistik der Kohlenwirtschaft) are another data source. The statistics provide a basic database and are used to verify findings relative to the coal sector.

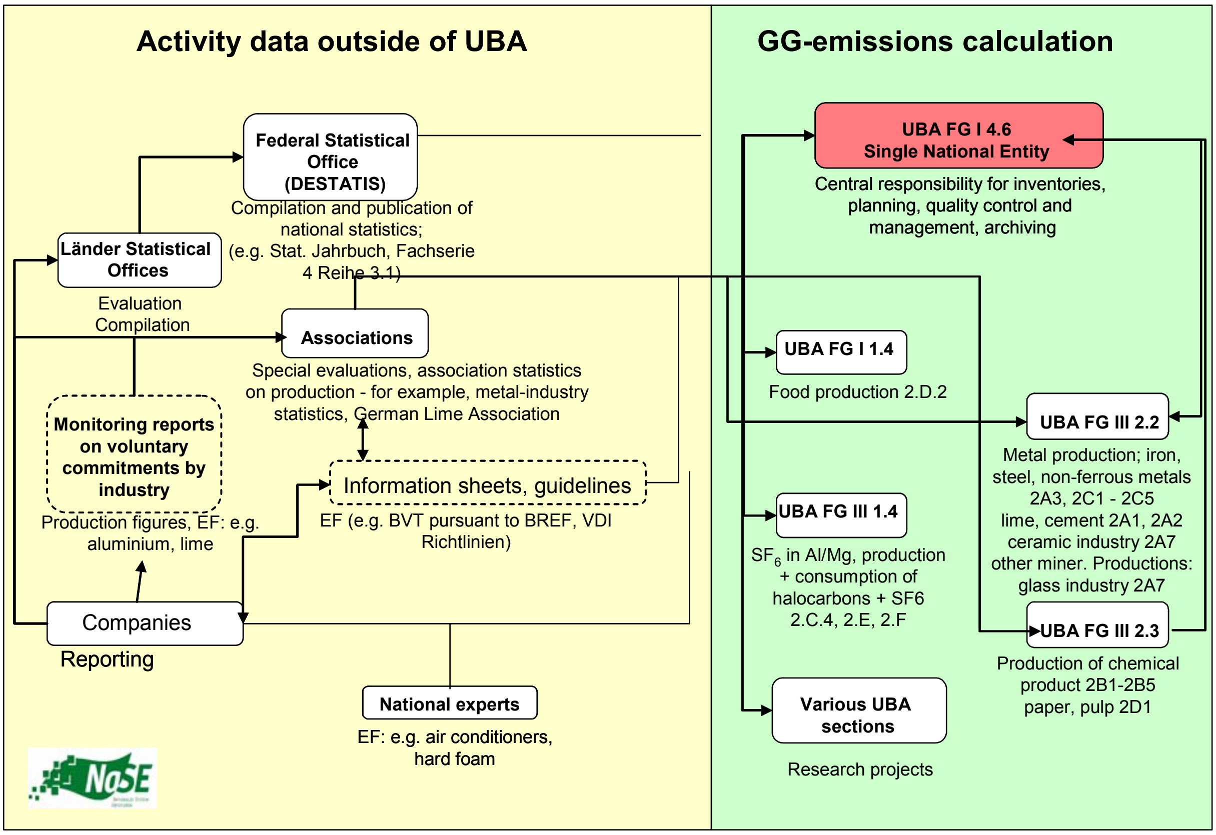
Calculations with the Federal Environmental Agency's module (cf. Chapter 3) are also based on the statistics *Leistung und Arbeit* ("Performance and Work") and *Betriebsmittel* ("Operating Equipment") of the German Electricity Association (*Verband der Elektrizitätswirtschaft; VDEW) e.V.* (hereinafter referred to as: VDEW Statistics). These statistics include performance data for power stations and steam production, as well as data on electricity generation. The VDEW Statistics have been discontinued. For this reason, it is not possible to update their data in the near term.

Yet another data source is the publication "Petroleum Data" (*Mineralöl-Zahlen)* of the Association of the German Petroleum Industry (*Mineralölwirtschaftsverband; (MWV) e.V.* (hereinafter referred to as: MWV Statistics)). This publication contains data on supply and consumption of petroleum in Germany, and it is broken down by source categories. The statistical data as published is very current (publication takes place within just a few months after the relevant survey).

Transport emissions are calculated primarily with the TREMOD model (”Transport Emission Estimation Model"; IFEU, 2005[10]. For calculation with TREMOD, extensive basic data from generally accessible statistics and special surveys was used, co-ordinated, and supplemented.

10 To permit derivation and evaluation of reduction measures, TREMOD is also used to calculate the energy consumption and CO_2 emissions of the individual vehicle categories. The values are subsequently aligned with total consumption and total emissions of CO_2.

1.4.1.2 Industrial processes



Source: ÖKO-INSTITUT, 2004a, modified

Figure 7: Responsibilities and data flows for calculation of greenhouse-gas emissions in the area of industrial processes

Various different sections within the Federal Environmental Agency are responsible for providing data for calculation of emissions from industrial processes.

Activity data is calculated on the basis of *Fachserie 4 Reihe 3.1* (Produktion im Produzierenden Gewerbe; Production in the manufacturing sector) and *Reihe 8.1* (Fachstatistik Eisen und Stahl; technical statistics for iron and steel) of the *Federal Statistical Office (DESTATIS Fachserie 4 Reihe 3.1, 1991-2004; DESTATIS Fachserie 4 Reihe 8.1, 1991-2004)*. These publications contain production data for the manufacturing sector. Reihe (Series) 3.1 appears on a quarterly and yearly basis, while Reihe 8.1 appears monthly and quarterly – i.e. both provide very current statistics.

Calculation of emissions from some industrial processes also draws on production data in *Verbandsstatistiken* (Association Statistics) and data from *Monitoringberichten* (Monitoring Reports*)* (cement clinkers, lime, primary aluminium production), data which industry, in the framework of monitoring of industry's compliance with its voluntary commitment on climate protection, has reported for several years and has been compiled and published by RWI (Rheinisch-Westfälisches Institut für Wirtschaftsforschung). The monitoring reports, however, are also based partly on data from industry *associations*. Prior to using such data sources, the Federal Environmental Agency checks the extent to which the relevant data covers all of the production for the source category in question.

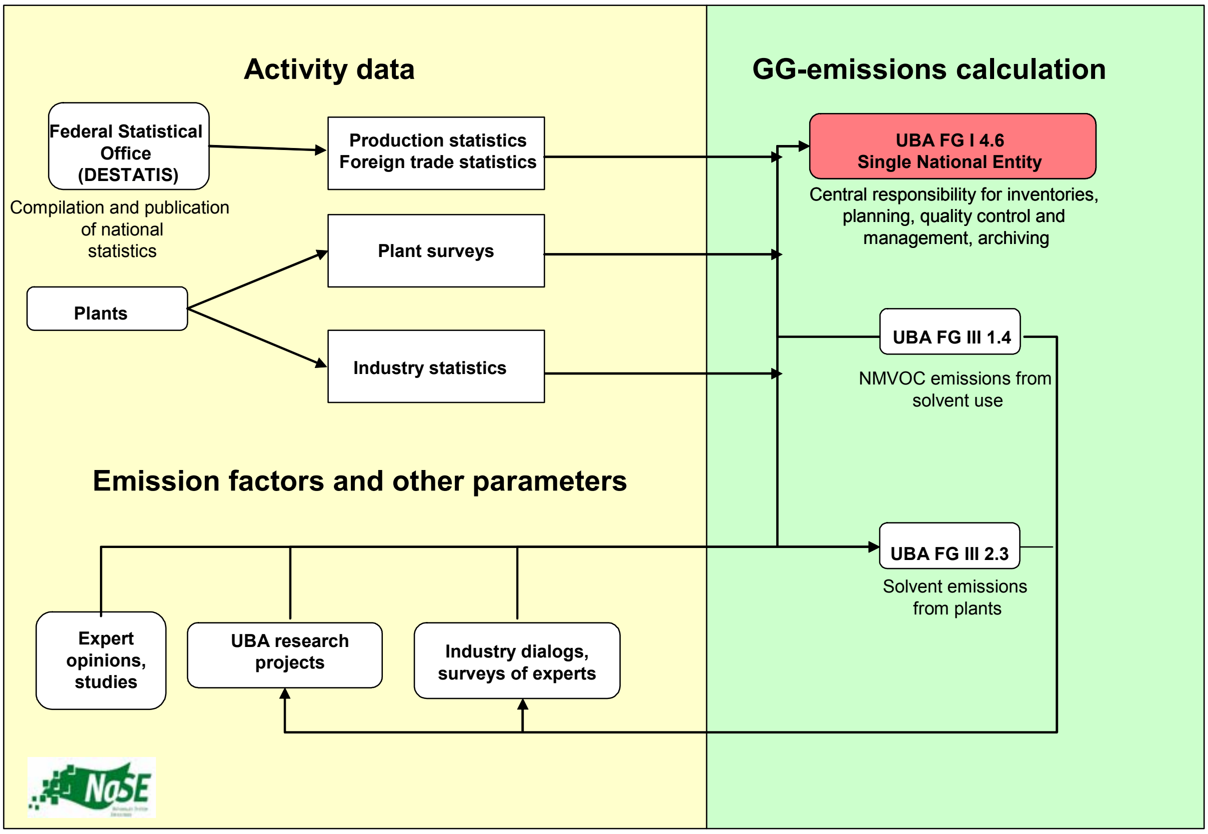
In the area of Other production: Pulp and paper production, data from the production report of the German Pulp and Paper Association (Verband Deutscher Papierfabriken VDP) is used.

In the area of 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, Agriculture and Consumer Protection (BMELV) is used.

In the area of consumption and production of halogenated hydrocarbons and SF_6, direct use is made of *manufacturers' data* and *surveys of manufacturers*, due to a lack of reliable statistical data. The great majority of the activity rates were researched directly in accordance with the inventory requirements, in the framework of a research project. Each of the various sub- source categories contains only a few companies.

Emission factors are obtained from national and international fact sheets and directives or via surveys of experts; where necessary, default values are used. More detailed pertinent information is presented in the descriptions of methods for the various source categories.

1.4.1.3 Solvent and other product use



Source: ÖKO-INSTITUT, 2004a, modified

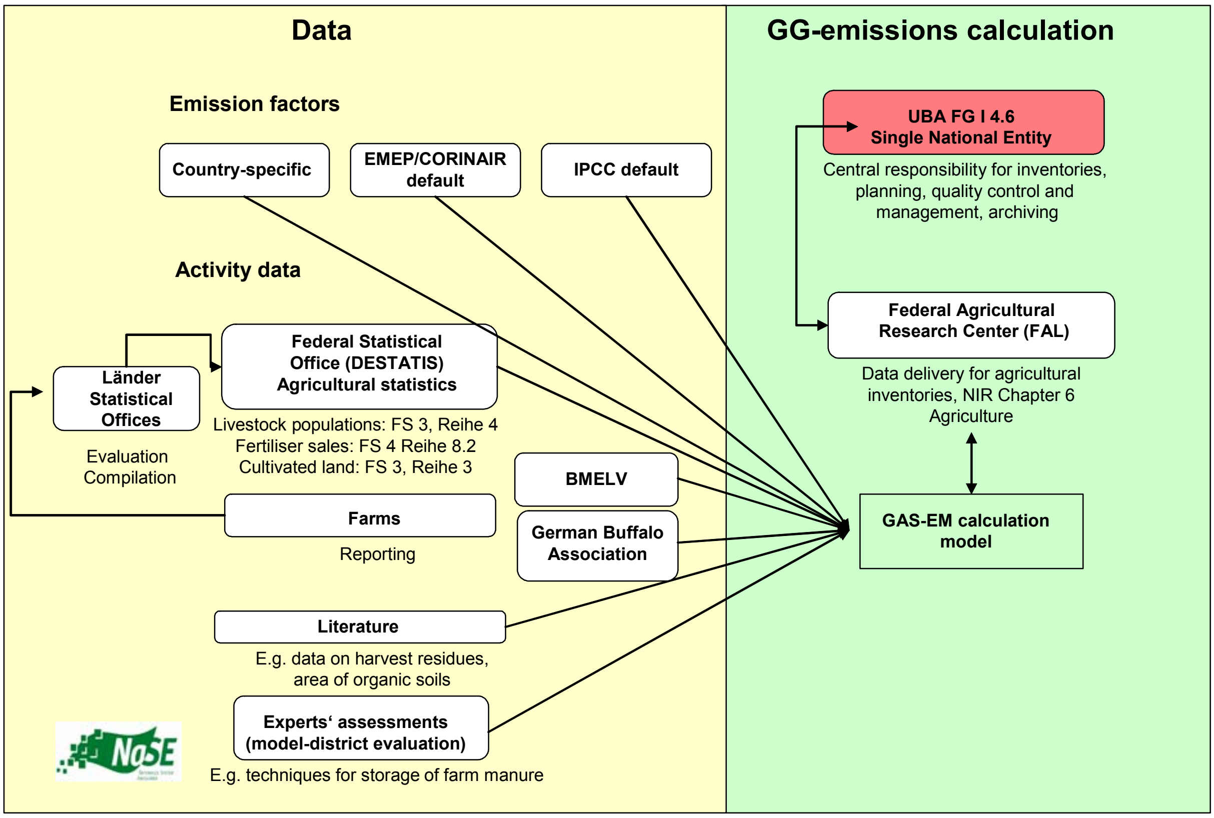
Figure 8: Responsibilities and data flows for calculation of greenhouse-gas emissions from use of solvents and other products

In the area of calculation of emissions from use of solvents and other products, the Federal Environmental Agency's section (FG) III 1.4 is responsible for selecting the methods, parameters and data used for calculating NMVOC emissions. The Federal Environmental Agency's section III 2.4, which supports section III 1.4 in the framework of that section's "global responsibility", is responsible for the sub-group of solvent emissions from facilities (such as painting, printing, etc.). The Federal Environmental Agency has not yet specified internal responsibilities for determining N_2O emissions from products.

Activity data is drawn mainly from published statistics of the Federal Statistical Office (DESTATIS), especially from its statistics on production and foreign trade. In some source categories and industry sectors, industry statistics are also used. Older surveys of facilities are used in the area of N_2O emissions from narcotic uses.

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

1.4.1.4 Agriculture



Source: ÖKO-INSTITUT, 2004a, modified

Figure 9: Responsibilities and data flows for calculation of greenhouse-gas emissions in the area of agriculture

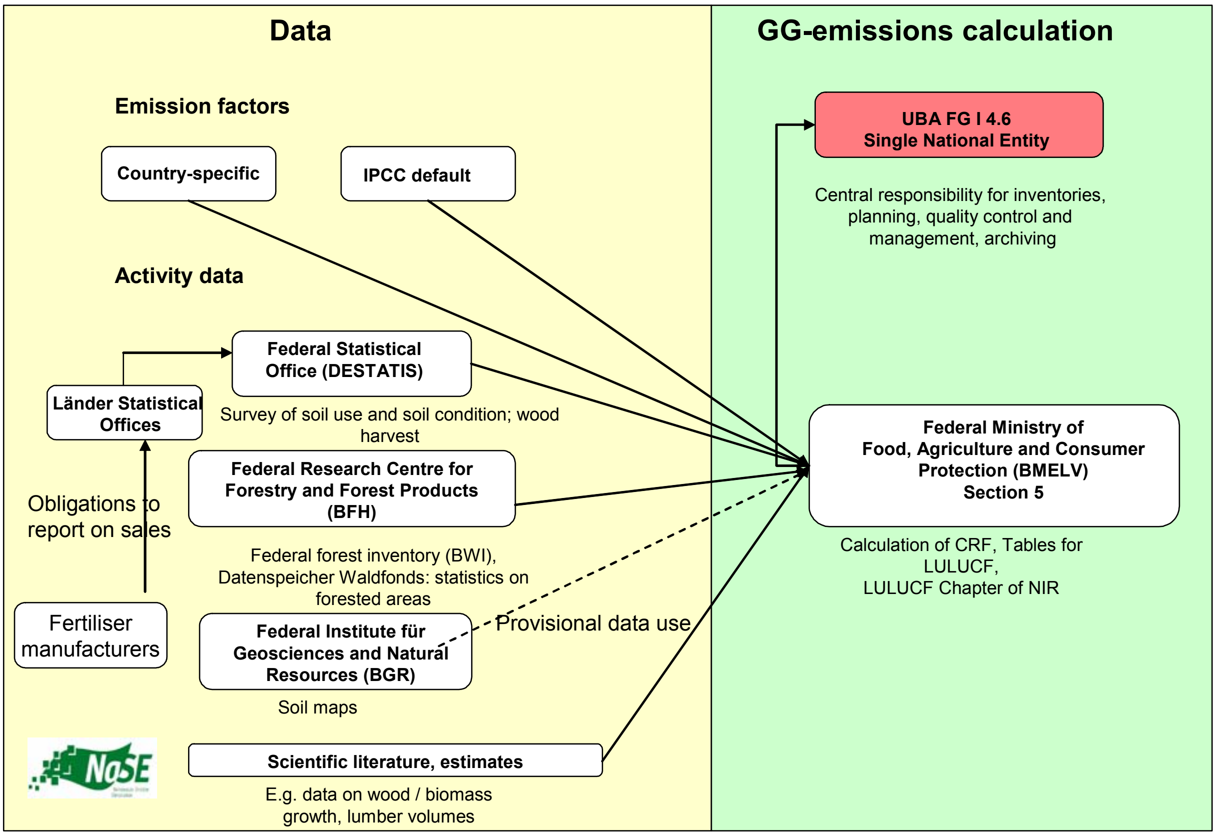
Calculation of emissions for Chapter 6 (agriculture) is carried out by the Federal Agricultural Research Institute (FAL). For calculation of agricultural emissions in Germany, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) initated a suitable joint project, in the framework of which the FAL developed a modular model for relevant spread-sheet calculation (GASeous Emissions, GAS-EM) (Dämmgen et al, 2002). The BMU and BMELV 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 taken from the Federal Statistical Office's relevant specialised *Fachserie* 3, *Reihe* 4 (DESTATIS Fachserie 3 Reihe 4:

no year). Other specialised series present statistics on fertiliser sales and on agricultural areas under cultivation. In some areas, such data is supplemented by figures from the pertinent literature (for example, harvest residues and area of organic soils). Additional data is 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 agricultural sector are based on simpler methods (EMEP/CORINAIR) or on Tier 1 methods – on methods that use standard emission factors from the Revised 1996 IPCC Guidelines or from the EMEP/CORINAIR manual of the United Nations Economic Commission for Europe (UN ECE). In addition, in a number of areas country-specific factors and parameters are used that have been taken from research projects and the literature and that the FAL has also compiled and integrated within the calculation model.

1.4.1.5 Land-use changes and forestry



Source: ÖKO-INSTITUT, 2004a, modified

Figure 10: Responsibilities and data flows for calculation of greenhouse-gas emissions from the area of land-use changes and forestry

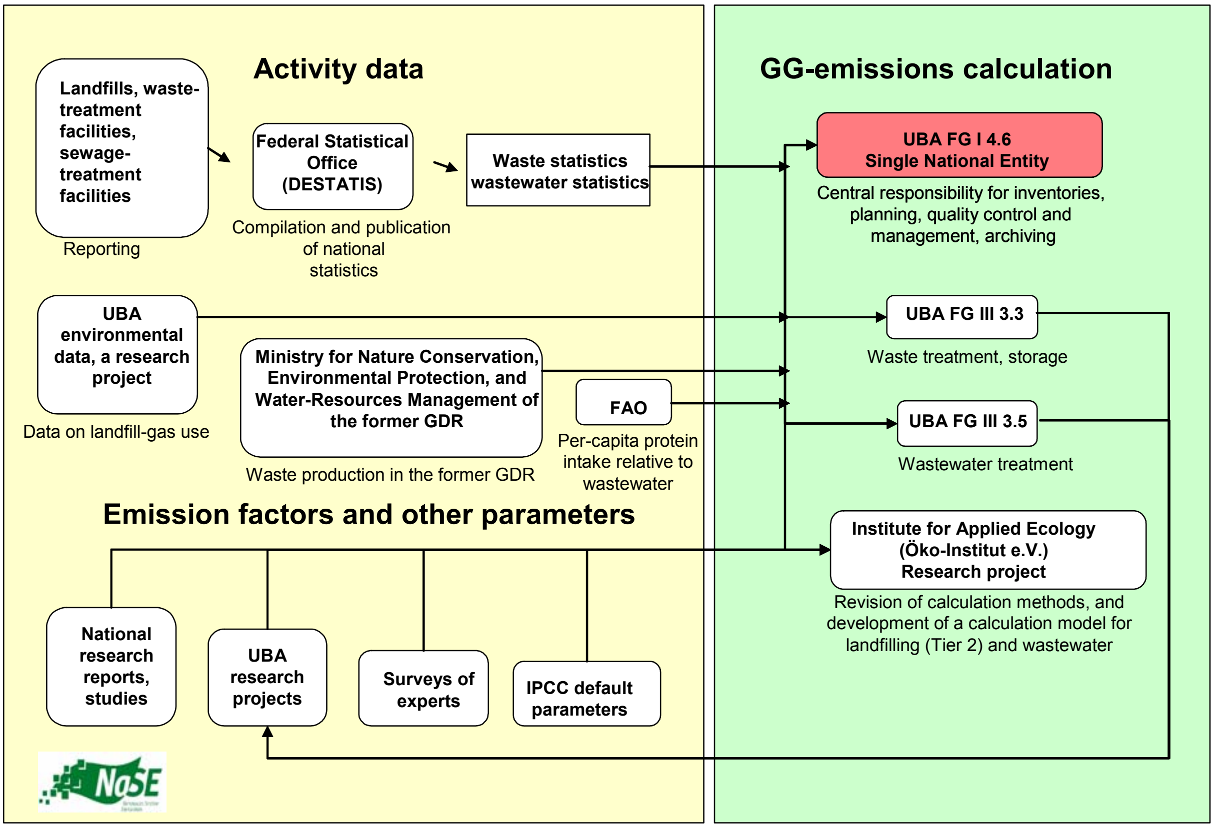
The changes in carbon stocks in forest biomass were derived for the first time for the 1990-2003 greenhouse-gas inventory. In the work, carried out on behalf of the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) by the Forest Research Institute Baden-Württemberg (Forstliche Versuchs- und Forschungsanstalt; FVA), the changes were derived primarily from the data of Federal Forest Inventories (Bundeswaldinventuren; BWI), in keeping with provisions of the Good Practice Guidance Land-Use, Land-use Change and Forestry (GPG-LULUCF, IPCC, 2003). For the 2005 inventory, the changes were updated, via extrapolation, by the Institute for Forest Ecology and Forest Surveys (Institut für Forstökologie und Walderfassung) of the Federal Research Centre for Forestry and Forest

Products (BFH). The activity data is based on the Federal Forest Inventories and on information from the Datenspeicher Waldfonds forest database. For further information, cf. Chapter 7.1.

As to determination of usage changes on agricultural areas, no activity data is yet available that fully meets quality requirements in this category. The activity data on CO_2 emissions and CO_2 storage in the soil needs to be supported by data on agricultural areas, as well as by quantitative and qualitative information (differentiated by types of usage and cultivation) for identification of land-use changes and by data for determination of carbon stocks in soils and in biomass. The relevant data used in these areas, which was taken from the area survey and from the main survey on soil use (Bodennutzungshaupterhebung; managed by the Federal Statistical Office), is available only aggregated by area; for this reason, the data can be used only in combination with additional data sources (e.g. remote sensing: CORINE Landcover) and with mathematical models developed especially for this case (and based on legal requirements and on empirical data). Soil carbon stocks are estimated with the help of soil maps provided by the Federal Institute for Geosciences and Natural Resources (BGR), while use-related changes in these stocks are estimated using emission factors derived from the scientific literature via multiple regression.

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. 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. In the first survey of the condition of forest soils (1987-1993) measured soil-carbon stocks in forests in the early 1990s, but it did not determine changes in stocks over time.

1.4.1.6 Waste and wastewater



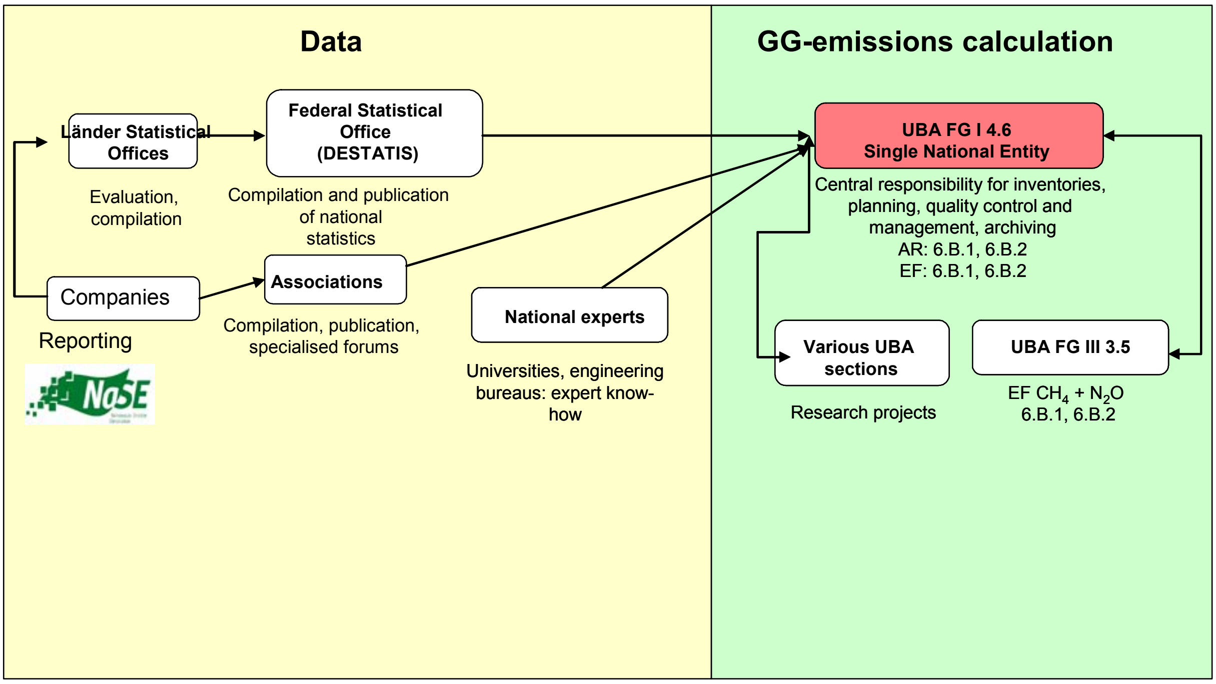
Source: ÖKO-INSTITUT, 2004a, modified

Figure 11: Data flows for calculation of greenhouse-gas emissions from the area of waste

Section FG III 3.3 is responsible for selecting the methods, parameters and data for calculating emissions from the waste sector. In recalculation of landfill emissions in 2003, the Federal Environmental Agency was supported by a research project (development of the Tier 2 method for the Federal Republic of Germany) (ÖKO-INSTITUT, 2004b).

Activity data in the waste sector is drawn mainly from published data of the Federal Statistical Office (DESTATIS), 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 on landfill-gas use are based on data from the publication "Daten zur Umwelt" (environmental data), which is published regularly by the Federal Environmental Agency. For 2001, data was also taken from a current research project.

The emission factors and other parameters that enter into calculation of emissions from waste landfilling and composting were taken from national studies and research reports conducted/prepared in research projects commissioned directly by the Federal Environmental Agency. IPCC default parameters were also used for this purpose. Individual 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.



Source: ÖKO-INSTITUT, 2004a, modified

Figure 12: Data flows for calculation of greenhouse-gas emissions from the area of wastewater

Section FG III 3.5 is responsible for selecting the methods, parameters and data for calculating emissions from the wastewater and sludge-treatment sector.

Activity data in the wastewater sector is drawn mainly from published data of the Federal Statistical Office (DESTATIS), 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 has been 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 reports conducted/prepared in research projects commissioned directly by the Federal Environmental Agency. IPCC default parameters were 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).

1.4.2 Methods

The methods used for the individual source categories are outlined in the overview tables for the various source categories and in summary tables 3s1 and 3s2 of the CRF reporting tables. For the individual calculation methods, a distinction is made between country-specific (cs) methods and IPCC "*Tiers*", in keeping with the source category[11].

With the exception of CO_2 emissions, road-traffic greenhouse-gas emissions were calculated with the help of the TREMOD model, which is based on a bottom-up Tier 2/3 approach. In compliance with the information from the Energy Balance for the Federal Republic of Germany, CO_2 emissions are calculated on the basis of a top-down Tier 1 approach.

For industrial processes, in many areas detailed IPCC tiers were used for the greenhouse gases HFCs, PFCs and SF_6. This was possible, in particular, because emissions for these greenhouse gases were surveyed specifically for emissions reporting, within the context of a new R&D project, and the relevant data was collated specifically with a view to application of the IPCC methods.

For agriculture, emissions were calculated primarily on the basis of the CORINAIR Guidebook, using IPCC default emission factors. Country-specific methods were applied only for agricultural soils (4.D).

Calculation for the waste sector was modified in line with the IPCC Tier 2 approach, and relevant new national data sources were developed (ÖKO-INSTITUT, 2004a).

All other source categories were shown in the IPCC Summary Tables as country-specific calculation methods. In this respect, it should be noted that the German inventories are currently being subjected to an intensive review process in which compliance of the applied methods with the IPCC approach is being systematically reviewed for the first time, and methodological changes are being implemented in order to conform to the *Good Practice Guidance*. As this methodological review is not yet complete, certain methods in the Summary Tables have been listed as country-specific even if it is not yet known whether IPCC conformity exists or which tier has been used. However, in the case of energy-related activity data, it can be assumed that Tier 1 has been used as a minimum. For other areas, too, classification will change from "country-specific" to IPCC tiers, since methodological conformity will either be ascertained or created during the course of the year.

1.5 Brief description of key categories

The key categories were defined by applying two Tier 1 procedures, Level (for 1990 and 2004) and Trend (for 2004, as compared to 1990), to German greenhouse-gas emissions.

11 *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.

For the first time in such a process, analysis focussed on both emissions from sources and storage of greenhouse gases in sinks. In the following compilations (and also in those in the Annex), analysis results are presented without inclusion of sinks. In the 3 analyses carried out without consideration of sinks, one source category was eliminated from each of the level specifications (1990: 2F – SF_6 from consumption of halocarbons and SF_6, 2004: 2B1 – CO_2 from ammonia production), while 2 key categories (1A3b – CH_4 from road transportation and 1A3d – Coastal and inland transport navigation) were eliminated from trend analysis. The reason for this was that source category 5 A Forest land proved to be an additional key category in all procedures that included the sinks. All specified key categories resulted from work in 2004 – they resulted either from level analysis for 2004 or from trend assessment.

For 2004, this approach identified 38 source categories, out of a total of 113 source and sink categories studied, as key categories. Only 21 of these were identified, by both trend and level analysis, as key categories. In addition, 8 source categories were identified as key categories solely by trend analysis, and 4 source categories were so identified solely by level analysis. Combination of the results of both types of analysis shows that a total of 97.07 % of greenhouse-gas emissions (not including LULUCF) – 1018864 Gg CO_2-equivalent emissions – in 2004 were released by the key categories. Identification of these source categories was based to a degree of 89.5 % on release of CO_2, to a degree of 4.2 % on CH_4 emissions, to a degree of 5.0 % on release of N_2O and to a degree of only about 1.3 % on F-gas emissions. This corresponds closely to the relevant overall relationships in the greenhouse-gas inventory.

Table 4 provides an overview of the results of analysis of key categories. Annex 1 (Chapter 12) of this report presents detailed explanations of the key category analysis carried out.

Table 4: Key categories for Germany pursuant to the Tier 1 approach (not including sinks)

IPCC Source Categories	Activity	Emissions Of	Level[#] 1990	Level[#] 2004	Trend[#] 2004
1A1a Public electricity and Heat production	all fuels	CO_2	●	●	●
1A1a Public electricity and Heat production	all fuels	N_2O			●
1A1b Petroleum Refining	all fuels	CO_2	●	●	●
1A1c Manufacture of Solid Fuels and Other Energy Industries	all fuels	CO_2	●	●	●
1A2a. Manufacturing Industries and Construction Iron and Steel	all fuels	CO_2	●	●	
1A2f Manufacturing Industries and Construction Other	all fuels	CO_2	●	●	●
1A3a Transport Civil Aviation	Aviation Gasoline	CO_2			●
1A3b Transport Road Transportation	all fuels	CH_4			
1A3b Transport Road Transportation	all fuels	CO_2	●	●	●
1A3d. Transport Navigation	Diesel Oil	CO_2			
1A4a Other Sectors Commercial/Institutional	all fuels	CH_4			●
1A4a Other Sectors Commercial/Institutional	all fuels	CO_2	●	●	●
1A4b Other Sectors Residential	all fuels	CO_2	●	●	●
1A4c Other Sectors Agriculture/Forestry/Fisheries	all fuels	CO_2	●	●	●
1A5 Other Include Military fuel use under this category	all fuels	CO_2	●		●
1B1a. Fugitive Emissions from Fuels Coal Mining and Handling	Solid Fuels	CH_4	●	●	●
1B2b Fugitive Emissions from Fuels Natural Gas	Natural Gas	CH_4	●	●	●
2A1 Mineral Products Cement Production		CO_2	●	●	●
2A2 Mineral Products Lime Production		CO_2	●	●	
2B1 Chemical Industry	Ammonia production	CO_2	●	●	●
2B2 Chemical Industry	Nitric Acid Production	N_2O	●	●	●

IPCC Source Categories	Activity	Emissions Of	Level# 1990	Level# 2004	Trend# 2004
2B3 Chemical Industry	Adipic Acid Production	N_2O	●		●
2B5 Chemical Industry	Other	CO_2	●	●	●
2C1 Metal Production Iron and Steel Production	Steel (integrated production)	CO_2	●	●	●
2C3 Aluminium Production		PFC´s			●
2C4 SF_6 Used in Aluminium and Magnesium Foundries		SF_6			●
2E Production of Halocarbons and SF_6	production of HCFC-22	HFC´s			●
2F Industrial Processes	Consumption of Halocarbons and SF_6	HFC´s		●	●
2F Industrial Processes	Consumption of Halocarbons and SF_6	SF_6	●		●
4A1 Enteric Fermentation	Dairy Cattle	CH_4	●	●	
4A1 Enteric Fermentation	Non-Dairy Cattle	CH_4	●	●	●
4D1 Agricultural Soils	Direct Soil Emissions	N_2O	●	●	●
4D3 Agricultural Soils	Indirect Emissions	N_2O	●	●	
5A Forest Land		CO_2			●
5B Cropland		CO_2	●	●	●
5C Grassland		CO_2	●	●	●
6A1 Managed Waste Disposal on Land		CH_4	●	●	●
6B1 Wastewater Handling	Industrial Wastewater	CH_4			●

#) without sinks

1.6 Information about the QA/QC plan

Pursuant to the IPCC *Good Practice Guidance* requirements, 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.

The international requirements for quality assurance and quality control measures in emissions reporting for the National System of Emissions Inventories (NaSE) in Germany have been specified in the "Manual for quality control and quality assurance in preparation of emissions inventories and reporting under the UN Framework Convention on Climate and EU Decision 280/2004/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 Environmental Agency, unpublished, 2005). This document, which is binding for the Federal Environmental Agency, describes the Quality System of Emissions Inventories (QSE).

A first systematic evaluation of all inventory data with regard to their quality in 2002 was carried out in research project 202 42 266 (UBA, 2004), which was designed to support implementation of requirements from the *Good Practice Guidance* in inventory preparation and which was charged both with preparing the QSE Handbuch and determining relevant uncertainties (cf. Chapter 1.7).

In this framework, a central quality assurance and control plan for the German inventory was also prepared. The QC plan was combined, in its document structure, with checklists for reviewing successful execution of quality controls. As a result, the checklists no longer require checking only; they also require documentation of achievement of specified quality targets (QC plan).

Such quality control checklists are to be filled out by NaSE participants[12] along with inventory preparation. They are designed to provide information about the quality of the data and methods on which the inventory is based. In 2005, the Federal Environmental Agency carried out systematic quality control, in the form of checklists, with the NaSE participants, for the first time. At the same time, this effort included only routine QC measures in keeping with Tier 1.

In early 2006, a subset of the improvement plan (Verbesserungsplan - VP) is to be integrated within the binding inventory plan (IP), which includes binding deadlines and competencies.

The two plans and the QC checklists taken together thus are an instrument for reviewing fulfillment of international requirements, and they make it possible to control inventory quality via initiation of quality assurance measures.

1.7 General uncertainty evaluation

IPCC Good Practice Guidance characterises determination of uncertainties as a key element of any complete inventory. As a result of the GPG's focus on continual inventory improvement, 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 source 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. This necessitates determination of 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.

In general, two methods for determining uncertainties are differentiated. The Tier 1 method combines, in a simple way, the uncertainties in activity rates and emission factors, for each source category and greenhouse gas, and then aggregates these uncertainties, for all source 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.

Research project 202 42 266 (UBA, 2004) carried out improved uncertainties determination in keeping with Tier 1 and Tier 2, pursuant to Chap. 6 of GPG. Plans for 2005 call for further improving this database and for completing uncertainties information for the greenhouse-gas inventory, to make it possible to report the inventory's uncertainty pursuant to the Tier 2 method. The relevant basis for this effort is currently being created.

In the current NIR, Germany reports uncertainties that have been calculated pursuant to the Tier 1 method. In determination of uncertainties in accordance with Tier 1, the uncertainties

[12] These persons include specialised experts (Fachverantwortliche - FV), specialised contact persons (Fachliche Ansprechpartner - FAP), quality control managers (Qualitätskontrollverantwortliche - QKV), the coordinator for the national inventory report (Koordinator für den Nationalen Inventar Report - NIRK), the coordinator for the National System (Koordinator für das Nationale System - NaSEK), the coordinator for the Central System of Emissions (Koordinator für Das Zentrale System Emissionen - ZSEK) and the coordinator for the quality system of emissions inventories (Koordinator für das Qualitäts-System Emissionsinventare - QSEK)

were estimated, wherever possible, by data-providing experts of the relevant Federal Environmental Agency sections and by external institutions. Table 5 provides an overview of the current known national uncertainties, as identified via completed experts' assessments:

Table 5: Completed experts' assessments for determining uncertainties pursuant to Tier 1

CRF	**Name**	Sub - source category	**AR**	**EF CO_2**	**EF CH_4**	**EF N_2O**	**EF PFC**	**Remarks**
1A	Energy - fuel combustion activities	Stationary sources	-	2002	2002 1990	2002 1990	NE	Complete uncertainty information (apart from small gaps)
1B2	Energy – fugitive emissions from fuels - oil and natural gas		2002 1990	NE	2002 1990	NE	NE	Complete uncertainty information, except for gas-distribution networks
2A1.	Industrial processes - cement production		-	2002	NE	NE	NE	
2A2	Industrial processes – lime production		-	2002	NE	NE	NE	
2C1	Industrial processes - iron and steel production		-	2002 1990	2002 1990	NE	NE	
2C3	Industrial processes - aluminium production		-	2002 1990	NE	NE	2002 1995	

For source categories that have not yet been assessed, the uncertainties underlying the adjustment procedure's "Conservativeness Factors" were used as provisional aids (FCCC/SBSTA/2003/ 10/Add.2). The results of the Tier 1 uncertainties analysis are described in detail in Annex 7, Chapter 18. The values used as provisional aids are marked with the quality indicator "D" (default).

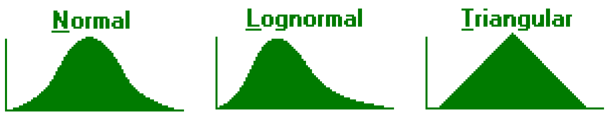
The description of uncertainties determination is preliminary, and it is confined to the Tier 1 approach. In early 2006, uncertainties are to be determined in accordance with Tier 2, for the German inventory, in the framework of an ongoing commissioned project. Only when this work has been completed can the chapter be adapted and updated.

1.7.1 Procedure for determining uncertainties pursuant to Tier 1, Chap. 6 of the GPG

For determination of uncertainties pursuant to Tier 1, experts' assessments were carried out in keeping with the guidelines in the GPG Chap. 6.2.5, "Expert Judgement". In addition to being guideline-based, experts' assessments made use of the current time series in the CSE for the years 1990 and 2003 and of all relevant available information. This includes the following questions:

- Are there comparable emissions sources with known uncertainties (transferability)?
- How well is the emissions process in question understood? Have all sources been taken into account?
- Do any physical limits apply to the emission factor (for example, as a result of the relevant mass balance, of the observed immissions values or of other process data)?
- Is the emissions data consistent with the observed immissions values?

Before the actual experts' assessment is carried out, the relevant source category's boundaries and its spatial and chronological references have to be precisely defined. This is accomplished by taking the current time series in the CSE into account, along with the time-series dimensions defined for the CSE. In the actual experts' assessments, intervals are defined. In the process, upper and lower boundaries, along with the most probable value, are estimated. Then, a distribution is assigned to these values. The distributions to select from include normal, log-normal and triangular distributions.



Where very little information is available for a given source category, only the extreme values are estimated. A uniform distribution of probabilities is then assumed for this interval.

Where adequate information is available, the experts' assessment can also be made step-by-step.

The results of the experts' assessment are recorded in a formalised way. In the process, reasons are provided for the assessment and the pertinent underlying information is documented.

With regard to degree of detail, uncertainties analysis was also carried out at the key category analysis level (i.e. key category analysis was carried out).

At present, uncertainties analysis does not cover the LULUCF area.

1.7.2 Results of uncertainty assessment

Pursuant to the Tier 1 analysis carried out for the year 2003, the overall uncertainty of the greenhouse-gas inventory amounts to +/- 5.6 %. Furthermore, the analysis has found an uncertainty of +/- 4.3 % for emissions development since 1990 (trend).

In general, uncertainties for activity rates can be assumed to be smaller than those for emission factors. In particular, the uncertainties are smaller for activity rates derived from fuel use and based on the Federal Energy Balance. On the other hand, uncertainties for activity rates 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 N_2O emission factors, since N_2O emissions are not monitored in normal cases. The same applies to the emission factors for CH_4.
- The uncertainties in the transport source category (primarily CRF 1 A 3) can generally be considered to be small, since precise relevant data on fuel use and vehicle fleets is 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 source category of fugitive emissions from fuels (CRF 1 B), the activity rates for oil and natural gas (CRF 1 B 2) include slight uncertainties, resulting from the fuels' being subject to taxation. Flaring of natural gas represents the only exception.

The activity rates for coal mining (CRF 1 B 1) are also well-represented by production volumes. 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 CH_4 emissions from coal mining have thus far been taken into account only as lump sums.

- Considerable uncertainties are seen in the area 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 in the association in question is organised. Among emission factors, uncertainties – which can be considerable, depending on the greenhouse gas in question – result, understandably, from strong technical dependence, coupled with extensive technical 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 provide relevant consolidated information. In addition, the uncertainties can be increased in that processes whereby non-combustion-related activities generate emissions are often very complex, in that too little is known about certain emissions-generating processes and in that too little is known about the relevant contributions of individual activities.
- In the area of production of alcoholic beverages, within the area of food and beverage 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 production volumes to be determined very precisely. The uncertainties for the relevant emission factors are larger, due to the industry's extensive technological diversification.
- The uncertainties for emissions parameters for the source categories managed waste disposal on land (CRF 6 A 1) and industrial wastewater (CRF 6 B 1) are presumed to be large. This applies especially to waste landfilling, since the diversity of the waste types involved tends to reduce the reliability of data for the relevant emissions parameters. The uncertainties for the activity rates are also disproportionately high, since the underlying statistical data makes use of non-standardised waste and recycling definitions. The general assumptions relative to the uncertainties of activity rates also apply to thermal treatment of waste.

Detailed information about the applicable uncertainties is provided in Annex 7 (cf. Chapter 18).

1.8 General checking of completeness

Details of completeness for the individual source categories are represented in CRF Tables 7s1, 7s2 and 7s3. 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 source-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). The separation of combustion-related and non-combustion-related emissions from industry has posed a number of difficulties; here, however, the avoidance of duplicate counting is generally an integral component of quality assurance.

Whereas fuel use for heat and power generation in the manufacturing sector, along with the relevant emissions, is recorded completely in the inventory, uncertainties persist in assignment of fuel use to the six source categories the inventory requires (1A2a through f). This can be partly attributed to contradictions between the Energy Balance and the Federal Statistical Office's data with regard to certain fuels (such as waste). To date, even experts in the field have been unable to resolve the discrepancies completely. These difficulties do not affect total fuel use or emissions in the manufacturing sector, however.

Extensive clarification is required especially with regard to activity rates in the area of coking plants and of refineries for blast-furnace gas, top gas and refinery gas.

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 source-category definitions and data-collection methods will continue to receive priority. In the area of industrial processes, no calculations are currently carried out for source categories 2.A.3 Use of limestone and dolomite, 2.A.4 Soda ash use, 2.A.5 Use of bitumen for roofing and 2.C.2 Production of ferroalloys. These source categories are not covered by the IPCC Good Practice Guidance, since the emissions from these categories are considered insignificant and since data for these source categories is usually not available. Both of the reasons that the IPCC gives for not covering these groups also apply to Germany. A research project relative to source category 2.A.3 Limestone and dolomite use has just begun; its purpose is to review such applicability and, if necessary, to include the previously ignored emissions within the inventory (FKZ 20541217/02).

In the area of agriculture, while survey data from a past research project on management systems in animal husbandry is available, an effort is being made to carry out periodic, representative data surveys, in the interest of the inventory's continuing completeness and consistency.

Some of the emissions data available to the Federal Environmental Agency is confidential, due to data-protection requirements, and thus is reported only in aggregated form – although it is reported completely. The draft bill (Referentenentwurf) of the Act on climate-protection statistics (Klimaschutzstatistikgesetz) includes a provision that would make it possible, in future, to completely check data, in spite of any applicable secrecy requirements.

In the framework of the R&D project 201 42 258, other countries' inventory data under the category "other sources" was analysed (ÖKO-INSTITUT, 2004a) in support of systematic review of completeness of national emissions data. This study was designed to show which of the source categories that other countries report on are also emissions-relevant in Germany – in order to expand German inventories accordingly, if necessary. This analysis showed that systematic review for completeness needs to be expanded, especially in the area of industrial processes, and it revealed that other countries treat geothermal systems – which Germany's reporting does not cover – as emissions-relevant. The results of this analysis will be incorporated in inventory planning.

2 TRENDS IN GREENHOUSE GAS EMISSIONS

Table 6 shows the total emissions, as determined for this inventory, of direct and indirect greenhouse gases and of the acid precursor SO_2. The associated annual progress over time compared with the base year of the Kyoto Protocol and 1990 is depicted in Table 7. With the exception of HFCs and of C_3F_8, significant reductions in emissions have been achieved for all the emissions calculated here. In total, emissions of greenhouse gases, calculated as CO_2 equivalent emissions, were down by 17.4 % compared to the base year. In comparison to the previous year, 2003, the emissions decreased by 0.9 %. This is due mainly to lower energy consumption for indoor heating and to emissions reductions in the coal-mining sector, resulting from increased use of pit gas.

Table 8 shows the relevant emissions changes, in comparison to the previous year, for the period since 1990. For CO_2, for example, the following emerges in addition to a continual decrease in emissions: in the years 1996, 2001 and 2003, which were cold by comparison to the development since 1990, additional energy had to be used for indoor heating, and this considerably increased CO_2 emissions in particular in those years, in comparison to the relevant previous years.

Table 6: Emissions of direct and indirect greenhouse gases and SO_2 in Germany since 1990

Emissions of greenhouse gases and of SO2 in Germany, 1990 -2004 [Gg][#)]															
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Directly acting greenhouse gases															
CO_2	1030231	995764	948423	938445	924409	920155	943608	914700	906672	881685	886258	899301	886480	892545	885854
CH_4	4752	4492	4293	4270	4061	3893	3755	3579	3335	3280	3091	2956	2817	2675	2450
N_2O	273	260	263	251	252	251	254	244	202	191	192	195	193	201	207
HFC [1)]	4369	4013	4098	4226	4357	6555	6044	6658	7257	7401	6556	7971	8647	8487	8802
CF_4 [Mg]	357	305	273	252	210	222	213	160	171	135	71	68	76	80	76
C_2F_6 [Mg]	42	38	36	35	31	32	34	32	34	32	25	19	21	23	22
C_3F_8 [Mg]	0	0	0	0	0	1	3	5	8	10	14	15	16	17	19
SF_6 [Mg]	200	214	236	268	280	302	295	289	280	222	213	205	176	180	187
CO_2-equivalent emissions	**1226671**	**1182029**	**1131817**	**1118496**	**1100468**	**1095116**	**1116126**	**1080503**	**1054662**	**1023720**	**1023219**	**1035330**	**1019066**	**1024800**	**1015692**
Indirectly acting greenhouse gases															
NO_X [2)]	2884	2651	2495	2385	2236	2140	2057	1985	1948	1925	1865	1773	1684	1616	1566
NMVOC	3585	3043	2776	2520	2247	2100	1974	1913	1842	1714	1513	1421	1320	1212	1234
CO	12095	9891	8562	7768	6844	6409	6086	6038	5646	5290	4994	4699	4437	4314	3668
Aerosol precursor															
SO_2	5322	3921	3223	2860	2400	1713	1430	1202	960	779	633	631	591	599	562

#) [Gg], except CF_4, C_2F_6, C_3F_8 and SF_6: [Mg]

1) in CO_2 equivalent emissions

2) as NO_2

Table 7: Changes in emissions in comparison to the base year of the Kyoto Protocol

Emissions trends in Germany with respect to the base year																		
					1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	Base year	Emission		%	+/- %													
Directly acting greenhouse gases																		
CO_2	1990	1021059	[Gg]	100,0	-3,3	-7,9	-8,9	-10,3	-10,7	-8,4	-11,2	-12,0	-14,4	-14,0	-12,7	-14,0	-13,4	-14,0
CH_4	1990	4538	[Gg]	100,0	-5,5	-9,7	-10,1	-14,5	-18,1	-21,0	-24,7	-29,8	-31,0	-35,0	-37,8	-40,7	-43,7	-48,5
N_2O	1990	273	[Gg]	100,0	-5,1	-4,0	-8,2	-7,9	-8,4	-7,0	-10,7	-26,3	-30,2	-29,7	-28,8	-29,5	-26,4	-24,2
HFC [1)]	1995	6555	[Gg]	100,0					0,0	-7,8	1,6	10,7	12,9	0,0	21,6	31,9	29,5	34,3
CF_4	*1995*	*222*	*[Mg]*	100,0					0,0	-4,3	-28,0	-23,1	-39,2	-68,3	-69,4	-66,0	-64,0	-66,0
C_2F_6	*1995*	*32*	*[Mg]*	100,0					0,0	5,1	-0,5	3,8	-2,1	-24,0	-40,2	-35,9	-27,3	-31,3
C_3F_8	*1995*	*1*	*[Mg]*	100,0					0,0	132,2	312,7	551,2	781,9	1147,1	1176,2	1281,6	1382,1	1561,0
SF_6	*1995*	*302*	*[Mg]*	100,0					0,0	-2,4	-4,4	-7,2	-26,5	-29,7	-32,2	-41,8	-40,4	-38,0
CO_2-equivalent emission		**1229963**	**[Gg]**	**100,0**	**-3,9**	**-8,0**	**-9,1**	**-10,5**	**-11,0**	**-9,3**	**-12,2**	**-14,3**	**-16,8**	**-16,8**	**-15,8**	**-17,1**	**-16,7**	**-17,4**
Indirectly acting greenhouse gases																		
NO_X [2)]		2878	[Gg]	100,0	-8,1	-13,5	-17,3	-22,5	-25,8	-28,7	-31,2	-32,5	-33,3	-35,3	-38,5	-41,6	-43,9	-45,7
NMVOC		3633	[Gg]	100,0	-15,1	-22,6	-29,7	-37,3	-41,4	-44,9	-46,6	-48,6	-52,2	-57,8	-60,4	-63,2	-66,2	-65,6
CO		12120	[Gg]	100,0	-18,2	-29,2	-35,8	-43,4	-47,0	-49,7	-50,1	-53,3	-56,3	-58,7	-61,1	-63,3	-64,3	-69,7
Aerosol precursors																		
SO_2		5288	[Gg]	100,0	-26,3	-39,4	-46,3	-54,9	-67,8	-73,1	-77,4	-82,0	-85,4	-88,1	-88,1	-88,9	-88,8	-89,4

[1)] in CO_2 equivalent emission
[2)] as NO_2

Table 8: Change in emissions in comparison to the previous year

Emissions changes in Germany since 1990 (percentage changes in comparison to the relevant previous year and to 2004/base year)																
	1990		**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2004 / Basisjahr**
Directly acting greenhouse gases																	
CO_2	1030231	[Gg]	-3,3	-4,8	-1,1	-1,5	-0,5	2,5	-3,1	-0,9	-2,8	0,5	1,5	-1,4	0,7	-0,7	-14,0
CH_4	4752	[Gg]	-5,5	-4,4	-0,5	-4,9	-4,1	-3,5	-4,7	-6,8	-1,6	-5,8	-4,4	-4,7	-5,1	-8,4	-48,5
N_2O	273	[Gg]	-5,1	1,2	-4,4	0,4	-0,5	1,5	-4,0	-17,4	-5,3	0,7	1,2	-0,9	4,4	3,0	-24,2
HFC	4369	[Gg]	-8,1	2,1	3,1	3,1	50,4	-7,8	10,2	9,0	2,0	-11,4	21,6	8,5	-1,9	3,7	34,3
CF_4	357	*[Mg]*	-14,5	-10,7	-7,4	-16,9	5,9	-4,3	-24,8	6,9	-21,0	-47,8	-3,7	11,3	5,8	-5,6	-66,0
C_2F_6	42	*[Mg]*	-9,7	-5,5	-3,1	-11,5	5,2	5,1	-5,3	4,3	-5,7	-22,3	-21,4	7,2	13,3	-5,5	-31,3
C_3F_8	0	*[Mg]*	-	-	-	-	-	132,2	77,7	57,8	35,4	41,4	2,3	8,3	7,3	12,1	1561,0
SF_6	200	*[Mg]*	7,0	10,1	13,7	4,5	7,9	-2,4	-2,0	-2,9	-20,8	-4,4	-3,5	-14,2	2,5	4,1	-38,0
CO_2-equivalent emission	1226671	**[Gg]**	-3,6	-4,2	-1,2	-1,6	-0,5	1,9	-3,2	-2,4	-2,9	0,0	1,2	-1,6	0,6	-0,9	-17,4
Indirectly acting greenhouse gases																	
NO_X [1)]	2706	[Gg]	-8,1	-5,9	-4,4	-6,3	-4,3	-3,9	-3,5	-1,9	-1,2	-3,1	-4,9	-5,0	-4,0	-3,1	-45,7
NMVOC	3221	[Gg]	-15,1	-8,8	-9,2	-10,8	-6,5	-6,0	-3,1	-3,7	-7,0	-11,7	-6,1	-7,1	-8,2	1,8	-65,6
CO	11213	[Gg]	-18,2	-13,4	-9,3	-11,9	-6,4	-5,0	-0,8	-6,5	-6,3	-5,6	-5,9	-5,6	-2,8	-15,0	-69,7
Aerosol precursor																	
SO_2	5321	[Gg]	-26,3	-17,8	-11,3	-16,1	-28,6	-16,5	-16,0	-20,1	-18,8	-18,8	-0,3	-6,3	1,2	-6,0	-89,4

[1)] as NO_2

2.1 Description and interpretation of the progress of aggregated greenhouse-gas emissions

By 2004, the above-described obligation to reduce greenhouse-gas emissions, in the framework of EU burden-sharing, had been largely fulfilled, via a reduction of 17.4 %. The individual greenhouse gases contributed to this development to varying degrees (see Table 1). This is hardly surprising when one considers that the individual greenhouse gases account for varying proportions of total emissions in a given year. Emissions of the direct greenhouse gases that predominate by amount were considerably reduced; CO_2 emissions decreased by 14.0 % and CH_4 and N_2O emissions were reduced by over 48.5 % and by 24.2 %, respectively. The reasons for these reductions are found in an entire group of measures, in basic categories such as fuel conversions, enhanced economic efficiency, changes in ways of keeping animals and reductions of numbers of animals kept. These measures are discussed in detail in the discussion below of trends for the various components.

The release of carbon dioxide from the processes of stationary and mobile combustion is by far the principal cause of emissions, accounting for 86.9 % 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 from 84.0 % to over 87 % since 1990 (cf. Table 2). Emissions of methane, which are caused primarily by animal husbandry, fuel distribution and landfill emissions, accounte for 5.0 % in 2004. Emissions of nitrous oxide, caused primarily by agriculture, industrial processes and transport, account for 6.3 % of greenhouse gas releases. The remaining so-called "Kyoto" or "F" gases together accounted for about 1.4 % of total greenhouse-gas emissions. This spectrum of distribution of greenhouse-gas emissions is typical for a highly developed and industrialised country.

2.2 Description and interpretation of emission trends, by greenhouse gases

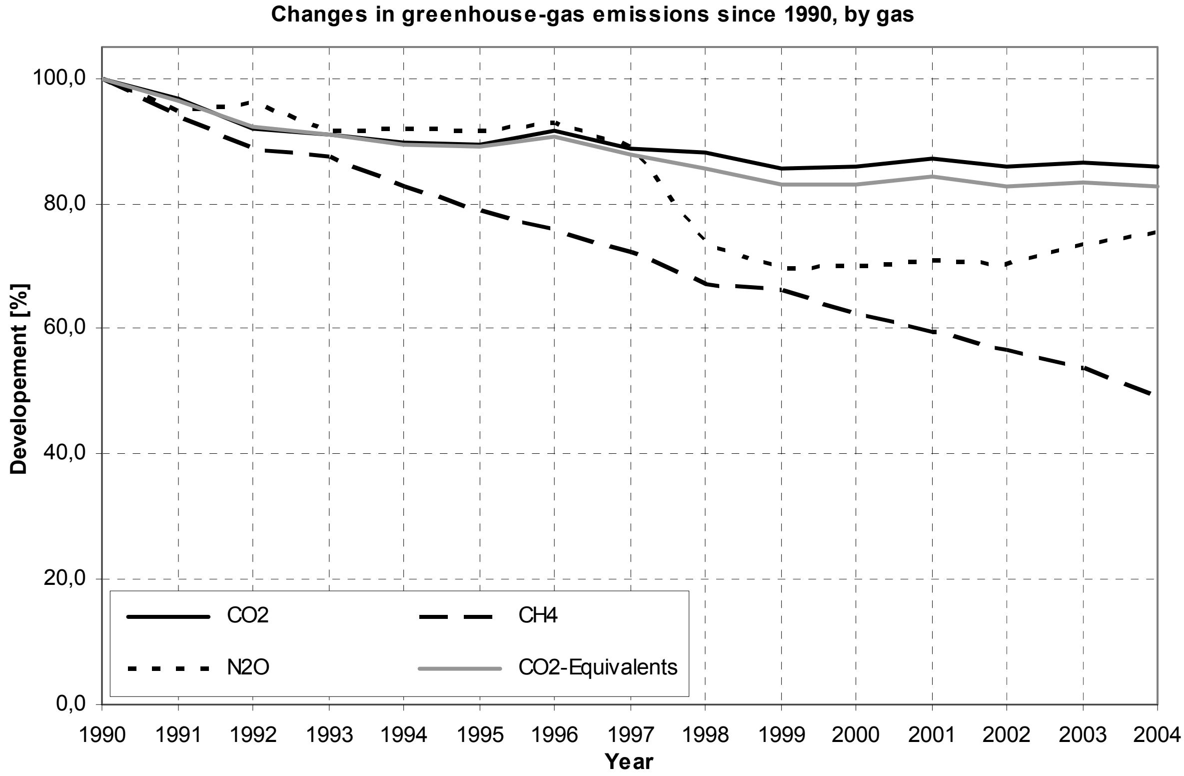


Figure 13: Relative development of greenhouse gases in comparison to 1990

Figure 13 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 source category. The reduction in CO_2 emissions is closely linked to the development in the energy sector. In this sector, fuel conversions, efficiency improvements via construction of new facilities – especially in the new Federal Länder – and extensive energy-saving measures led to a considerable emissions decrease. For example, CO_2 emissions from public power and district-heat generation decreased by 10 million t since 1990. In the process, the mix of fuels used changed considerably – while energy-sector emissions from use of solid and liquid fuels sank by 16 % and 7 %, respectively, CO_2 emissions from use of gaseous fuels increased by 29 %. This trend is even more pronounced in the area of households and small consumers. In this area, emissions decreased by a total of over 17 %, between 1990 and 2004 – from 204 million tonnes of CO_2 to about 169 million tonnes of CO_2. In 1990, solid fuels were still contributing 33 % of these emissions. By 2004, their contribution had fallen sharply, however – to 2 %. The corresponding percentages for gaseous fuels, on the other hand, increased considerably, from 22 % to 52 %. Similar developments have also taken place in the transport sector – although here emissions have been increasing markedly overall. CO_2 emissions increased from 162 to about 171 million t, and use of diesel fuel increased disproportionately. In 1990, nearly 2/3 of all road-traffic emissions were still being caused by petrol consumption. In 2004, the balance between petrol-related (48.3%) and diesel-related emissions (51.7%) reversed for the first time.

N_2O emissions decreased by over 24 % in the period under consideration. The main sources were use of nitrogen-containing fertilisers in agriculture, industrial processes in the chemical sector, stationary and mobile combustion processes and animal husbandry in agriculture. Smaller amounts of emissions are caused by wastewater treatment and product use of N_2O (for example, as an anesthetic). Industry has the greatest influence on emissions reductions, especially in the area of adipic acid production. In this respect, in 1997 producers in Germany completed a process of retrofitting their production systems with emissions-reduction equipment. This reduced emissions from the chemical industry by nearly 47 %, in relation to the corresponding level in 1990. Decreased fertiliser use in agriculture also contributed to the reduction of total emissions.

Methane emissions are caused mainly by animal husbandry in agriculture, waste landfilling and distribution of liquid and gaseous fuels. These emissions loads play an almost negligible role in comparison to that of energy-related and process-related emissions. These emissions have been decreased by over 48 % since 1990. This trend has been the result of political environmental protection measures (green dot on recyclable products, yellow sacks for recycling pickups, increased recycling overall and increasing energy recovery from waste) that reduced amounts of waste for landfilling. A second key reason is that use of pit gas from coal mining, for energy recovery, has increased. Emissions in this sector decreased by over 60% since 1990, and by over 20% in comparison to the previous year. Another reason for the emissions reductions is that livestock populations in the new Federal Länder were reduced, especially in the first half of the 1990s. Repairs and modernisations of outdated gas-distribution networks in this part of Germany, along with introduction of gas balancing in fuel distribution, brought about further reductions of total emissions.

Figure 14 shows emissions trends for so-called "F" gases for the period 1995-2004. HFC emissions increased, primarily as a result of intensified use of these substances as refrigerants. This counteracted emissions reductions resulting from their reduced use in PU installation foams. The emissions reductions for PFCs were achieved primarily through efforts of primary aluminium producers and semiconductor manufacturers. The reduction in the SF_6 emissions 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 soundproofed windows, for which production use of SF_6 has been reduced to one-tenth of its level in 1995. Much of current and future emissions of this substance (will) result from open disposal of old windows. Emissions from electricity-transmission facilities also decreased considerably.

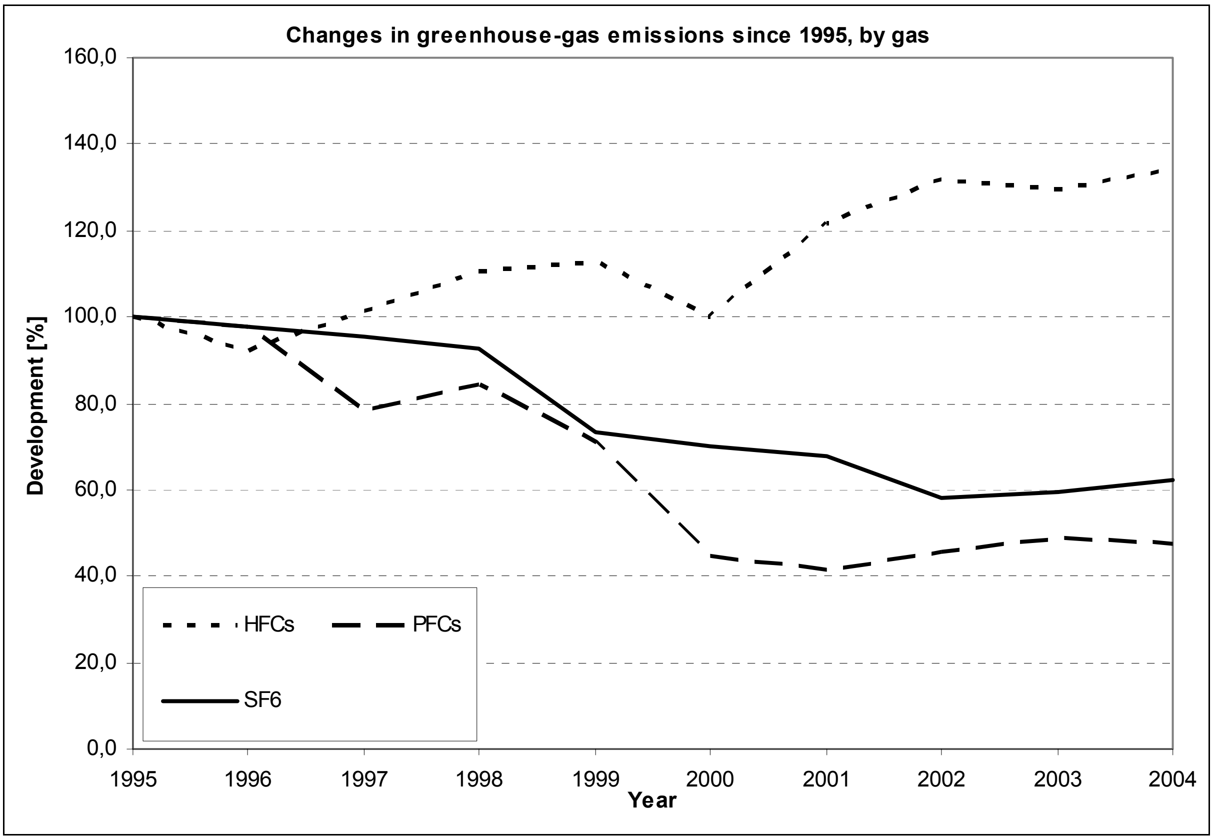


Figure 14: Relative development of F gases in comparison to 1995

2.3 Description and interpretation of emission trends, by source categories

Table 9: Relative development of greenhouse gases in comparison to 1990, by source categories

Relative development of greenhouse gases in comparison to 1990, by source categories [%]															
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Energy	0,0	-3,2	-8,1	-8,8	-11,0	-11,6	-8,9	-12,4	-13,3	-15,5	-15,7	-14,0	-15,3	-14,8	-16,0
Industrial processes	0,0	-4,2	-4,1	-7,1	-0,3	1,1	-2,0	0,4	-11,3	-18,4	-15,8	-16,8	-16,7	-14,0	-10,5
Solvents and other product use	0,0	-4,0	-8,0	-11,9	-15,9	-19,9	-23,9	-27,9	-31,8	-35,8	-39,8	-43,8	-43,8	-43,8	-43,8
Agriculture	0,0	-9,7	-12,2	-13,8	-16,6	-14,7	-14,7	-16,1	-15,8	-14,1	-13,9	-14,8	-17,1	-17,4	-18,3
Land-use changes and forestry*)	0,0	3,0	5,4	7,1	9,4	10,3	11,9	13,3	14,2	15,8	20,2	22,9	23,7	25,5	26,9
Waste and wastewater	0,0	-0,2	-1,8	-4,9	-10,0	-15,4	-21,5	-28,5	-35,0	-40,6	-45,8	-50,8	-55,4	-59,9	-63,8

*) This category is a net sink.

Among energy-sector emissions, which have been decreasing, combustion-related emissions are shaped 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. This situation is exactly the opposite for energy-related emissions that are not combustion-related. In this area, CO_2 emissions play a negligible role, 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 over 16.0 % since 1990. For combustion-related emissions, this has been achieved through fuel conversions and higher energy and technical efficiencies, whereas for distribution emissions it is due to increased use of pit gas, to modernisation of gas-distribution networks and to the introduction of vapour-recovery systems in fuel distribution.

In the area of emissions from industrial processes, CO_2-emissions contributions have been relatively constant in the lime and cement manufacturing sector and in the iron and steel industry. Reallocation of emissions from the iron and steel industry, to energy-related and process-related emissions, has cast a different light on this development, however. The trend for this source category, in which the reduction amounts to nearly 14 %, has been shaped primarily by emissions-reducing measures in adipic acid production, which have led to marked reductions in N_2O emissions. Introduction of such measures, by producers in Germany, sharply reduced emissions in 1997. Emissions increased over the previous year's level via increased production of cement and iron and steel.

Emissions in the area of solvent and product use are not particularly high, in absolute values. Emissions from narcotic use of N_2O decreased by nearly 44 % since 1990. That is a finding of a balance taken for the years 1990 and 2001. The results were interpolated for the period between the two years, and then, due to a lack of later data, the same relevant figure was used regularly for the period after 2001. The next chapter discusses the relevant solvent emissions themselves.

The reduction of emissions from agriculture is due primarily to reductions in livestock herds. In addition, decreasing use of mineral fertilisers has also reduced emissions. In comparison to their 1990 levels, they decreased by over 18 %.

The 26% increase in greenhouse-gas storage via "land-use changes and forestry" is due primarily to a reduction of CO_2 emissions from agriculturally cultivated soils and to an increase in the forest area.

The most significant emissions reduction, at nearly 64 %, occurred in the area of waste emissions. In this area, intensified recycling of recyclable materials ("yellow sack" for recyclable materials, Ordinance on Packaging, etc.) has reduced annual amounts of landfilled waste and thus has reduced landfill emissions. Emissions from wastewater treatment, which also belong to this source category, are considerably lower, in terms of amounts, than landfill emissions.

2.4 Description and interpretation of the progress of 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 15 and in Table 7Over this period, a number of significant successes have been achieved in reducing these pollutants. For example, emissions of SO_2 were reduced by almost 90 %, those of CO by nearly 70 %, those of NMVOCs by 64 % and those of NO_X by 6 %.

The reasons for this development listed below are more or less relevant for all of the components considered in this context:

- As a result of Germany's reunification in 1990, emissions from the territory of the former GDR in particular made the starting level comparatively 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.
- 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 traffic sector, newer vehicles equipped with pollutant-reducing technology were used.
- 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 were repeatedly adapted in line with the latest state of the art.
- Established legal and market-economic regulations led to thriftier use of energy and raw materials.
- International legislation, particularly from the European Community, has had an emission-reducing effect (e.g. the NEC Directive).

Descriptions of the emission calculations for these pollutants, along with additional, detailed parameters influencing the emission trends of the individual air pollutants, are provided by the Website of the Federal Environmental Agency.

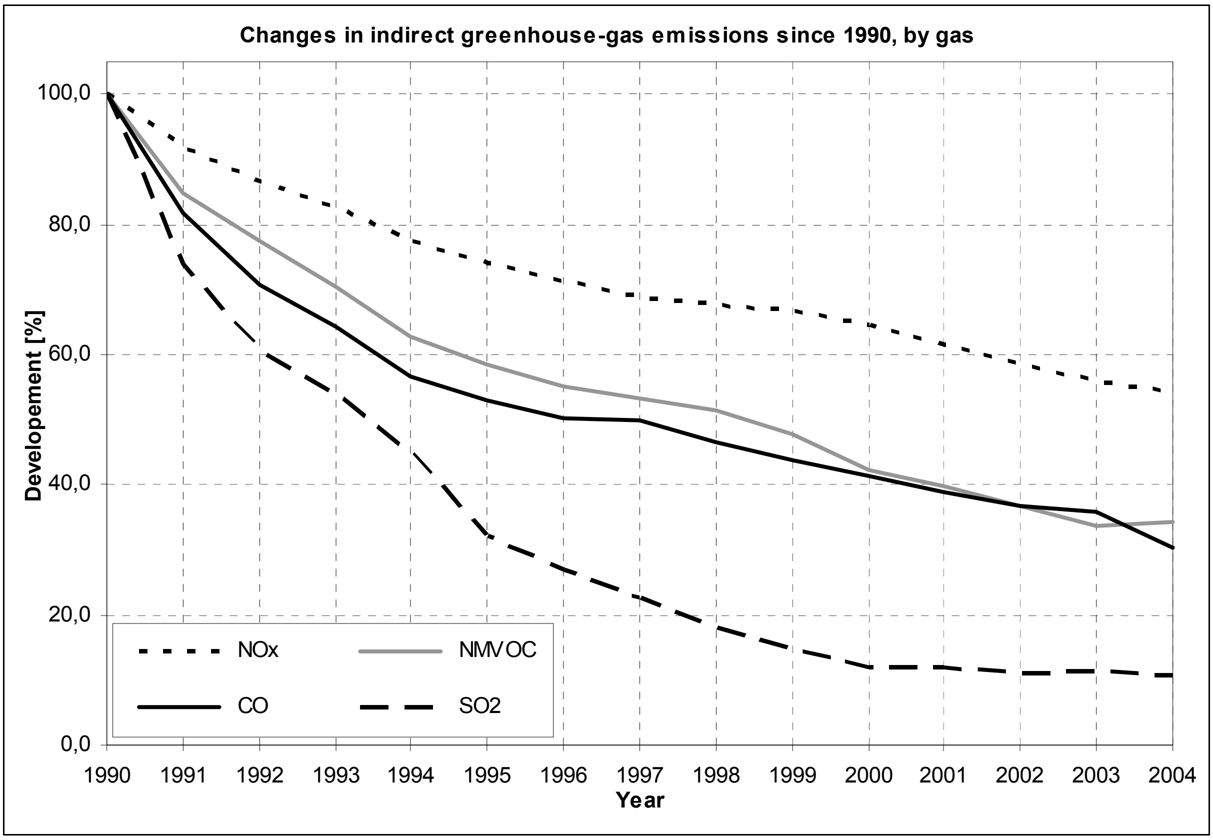


Figure 15: Relative development of emissions of indirect greenhouse gases and of SO_2

3 ENERGY (CRF SECTOR 1)

In the Federal Republic of Germany, energy statistics are published by numerous agencies, and these statistics differ in part in terms of their representation, delimitation and aggregation. Against this background, in the early 1970s, associations of the Germany energy industry, along with economic research institutions, formed the Working Group on Energy Balances (AGEB), aimed at evaluating statistics from all areas of the energy industry on the basis of uniform criteria, combining the data into a well-rounded picture, and making these figures available to the general public in the form of energy balances (ZIESING et al., 2003). In 2004, the Working Group on Energy Balances was refounded as an association (Verein). The energy balances of the Federal Republic of Germany command a pivotal position in the energy data system by virtue of their structure and conclusiveness. They therefore form the basis for determination of energy-related emissions and for development of scenarios and forecasts of the effects of energy policy and environmental policy measures.

The members of the Working Group on Energy Balances include six energy-sector associations and three economic research institutes. A list of members is provided in Chapter 13.1. Further information with regard to the AGEB and its database (Chapter 13.1), to development of energy balances (Chapter 13.2), to reallocation of statistical differences (Chapter 13.3), to preparation of provisional energy balances (Chapter 13.4), to methodological aspects of determination of energy-related activity rates (Chapter 13.5) and to uncertainties and time-series consistency (Chapter 13.6) is provided in Annex 2 (Chapter 12).

The emission factors on which the inventory is based have been derived from the list of CO_2 emission factors for the German National Allocation Plan (cf. Chapter 13.8).

The emission factors used are based on the assumption that the carbon contained in fuels is completely oxidised. For this reason, the oxidation factor in the calculations was set to "1".

3.1 Combustion of fossil fuels (1.A)

The area of *combustion of fossil fuels* comprises stationary sources with combustion-related emissions. In the energy balance, this refers to the following items:

A: Transformation input

- Public thermal power plants (line 11 of the energy balance in the structure from 1995 onwards)
- Industrial thermal power plants (line 12)
- Heat plants (line 15) and
- District heat plants (line 16)

B: Energy consumption in the transformation sector (own consumption)

- Coke ovens (line 33)
- Hard coal pits and briquette plants (line 34)
- Lignite pits and briquette plants (line 35)
- Crude oil and natural gas production (line 37)
- Refineries (line 38)
- Other energy producers (line 39)
- Sum total of own consumption (line 40)

C: Final energy consumption

. Quarrying of nonmetallic minerals, other mining and manufacturing industry (line 60)
. Households (line 66)
. Trade, commerce, services and other consumers (line 67)

Regarding the content and delimitation of these items, the following explanations are required:

4. ***Public thermal power plants*** (line 11) are plants that feed produced electricity into the public grid. This also includes industrial plants which operate their power stations together with electricity utility companies as joint 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 plants attributable to electricity production.
5. ***Industrial thermal power plants*** in energy balance line 12 comprises the following operator groups:
   a) Power plants in hard coal mining
   b) Power plants in lignite mining
   c) Power plants in petroleum processing (refinery power stations)
   d) Power plants which generate single-phase electricity for the German national railway, Deutsche Bahn AG (facilities owned by the railway, as well as public and industrial power plants which generate electricity on behalf of Deutsche Bahn AG). As of 2000, for balancing purposes these plants are listed under Public thermal power stations (line 11); in the inventory, they continue to be listed under 1A2.
   e) Industrial power plants (quarrying, other mining, manufacturing industry)
6. For thermal power plants in line 15 of the energy balance, only the fuel input which can be allocated to district heati generation is given. Adding lines 11 and 15 together produces the total fuel input in public thermal power plants. The district heat generated is fed into the public heating grid. These plants also supply industrial customers with process heat.
7. In energy balance line 16, ***district heat plants*** indicates the fuel input for the public district heating supply. The plants are often used to cover peak loads in district heat networks in which the basic load is met by combined heating and power stations.
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. In this instance, no distinction is made according to the type of heat generation. This means that fuel inputs for heat generation in combined heating and power plants, steam and hot water boilers and process firing installations are combined. There is an inconsistency in the energy balance with respect to lignite pits and briquette plants. The fuel used in combined heat and power generation to generate heat (for drying the crude lignite in lignite briquette plants) is reported together with the transformation input (line 10), even though this is only materially transformed. The emission-causing use of lignite is calculated out during data preparation.
   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.

9. ***Final energy consumption by industry*** (line 60 of the energy balance) indicates the fuel used for heat generation which is required for both production purposes and room heating. Here as well, no distinction is made according to the type of heat generation. Hence, part of the final energy consumption in these source categories, together with industrial power stations' fuel input for generating electricity, constitutes the total fuel input in such plants.
10. The data on ***final energy consumption by households*** (line 66 of the energy balance) lists fuel inputs for heat generation and includes the application areas of heating, hot water production and cooking.
11. The data on ***final energy consumption by trade, commerce, services and other consumers*** (line 67 of the energy balance) comprises fuel inputs used for hot water production, room heating and process heat generation in this sector.

The data in the energy balance is no longer sufficient to accommodate the diverse requirements of national and international energy and emissions reporting. For example, the energy balance combines fuel inputs which

- Are used in plants with differing requirements under immission protection legislation (e.g. large furnaces, medium-sized furnaces, small furnaces, waste incineration plants)
- Operate according to different technical principles (e.g. steam turbine power stations, gas turbine power stations, motor power stations)
- Exhibit regional peculiarities (e.g. different individual mining regions have different qualities of crude lignite)
- Are allocated to different source categories in national and international emissions reporting
- Are listed in various energy balance lines according to their intended purpose (for electricity or heat generation) but are used in a single plant group (e.g. steam turbine power stations).

These characteristics have impacts on emissions behaviour. In order to make allowance for these differing requirements, the Federal Environmental Agency has developed a module entitled *Balance of Emission Causes* (BEU) and has disaggregated the energy balance using additional statistics as well as its own calculations. In this way, the *fuel combustion module*, which is summarised in 8 lines in the energy balance, can be further sub-divided into 88 lines (tables). Of these, 66 are tied to emissions-causing fuel input in stationary combustion, which is considered in this section.

Balance of emission causes (BEU)
▪ Sector, ▪ Plant type, ▪ Fuel, ▪ Immission protection provision, ▪ Energy balance line, ▪ (Where necessary: regional allocation), ▪ Allocation to the Central System of Emissions (CSE)
The source categories include: ▪ Public thermal power stations, ▪ Hard coal mining, ▪ Lignite mining, ▪ Deutsche Bahn AG *(German national railway),* ▪ Petroleum oil refineries, ▪ District heating stations, ▪ Other transformation sector (may be further sub-classified) ▪ Quarrying of non-metallic minerals, other mining and manufacturing industry (further sub-classification planned) ▪ Households, ▪ Trade, commerce, services and other consumers
Plant types 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 15 processes).
By fuels/energy sources: ▪ 21 energy sources
On the basis of immission protection legislation provisions, a distinction is made between: ▪ Facilities under the 1st Ordinance on the Execution of the Federal Immission Control Act (13. BimSchV), ▪ Facilities under the 1st Ordinance on the Execution of the Federal Immission Control Act (17th BImSchV), ▪ Facilities under the 1st Ordinance on the Execution of the Federal Immission Control Act (1. BimSchV), ▪ Installations under the Technical Instructions on Air Quality Control (TA Luft)

Abbreviations stand for:

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 16: Characteristics of the Federal Environmental Agency's structure of the Balance of Emission Causes, for disaggregation of the Energy Balance

Figure 16 presents the characteristics of the BEU structure, while Table 10 through Table 14 show the BEU structure itself. These basic structures are analysed in greater detail in the following account of activities. This information needs to be accompanied by the following explanations:

The number in the first column corresponds to the consecutive number in the table in the *Balance of Emission Causes*. The number in the third column is the line number of the energy balance from which the basic data for calculation in the *Balance of Emission Causes* table is used. The column "SWK" (S = fuel input for electricity generation, W = fuel input for heat generation, K = fuel input for machine action) shows the use in question. The "file name" in the eighth column refers to the database of the *Central System of Emissions (CSE)*.

The purpose of the BEU module is to provide a data structure that can be transferred into the various relevant formats for required national and international reports. Although the manner in which the data is arranged may differ, the same total group of data categories may thus always be assumed to be present. In particular, on this level no differentiation is made between fuel uses that are relevant only with regard to climate protection and uses that are relevant only with regard to immissions control. The relevant importance in each case may be determined from the emission factors.

To date, the time series cover the period from 1987 to 2004 (from 1987 through 1994, for the former territory of the Federal Republic of Germany and the former GDR and, later, the old and new Federal Länder; as of 1995, for Germany as a whole). In this representation, calculations from 1991 to 1994 for the new *Länder* are not yet complete, which means that no complete data for emission causes from stationary sources is currently available for Germany for this period. Data for the period 1999 to 2004 is provisional.

Despite the conversion of the energy balance to the new classification of industrial sectors (WZ 93) and the altered grouping of energy resources from the year 1995 onwards, we have so far succeeded in fitting the data within the outlined basic structure, thereby facilitating the preparation of consistent time series.

Further documentation on the data in the BEU module is provided in Chapter 13.8.

In a research project, the 1990 fuel inputs for the new German Länder were revised and substantiated (cf. Annex 14.1.1). This applies to source categories 1.A.1 and 1.A.2. The data for the new German Länder for 1990 is based on continued use of the last available GDR statistics, dating from the year 1989. This revision produced inconsistencies with the subsequent years 1991-1994, and thus the activity rates for 1991-1994 had to be revised as well. This work is expected to be completed by spring 2006.

Table 10: Structure of the balance of emissions causes – public services

No.	Process, fuel	EB line	Classification under emissions laws	Type of facility[1)]	Economic sector	SWK[2)]	File name	Remarks
Public services								
1	Electricity generation in large combustion systems of public power stations	11	13th BImSchV	DTKW	Public services	S	OEKW13	
2	Electricity generation in large combustion systems of public crude-lignite-fired power stations	11	13th BImSchV	DTKW	Public services	S	OEBKW13	
2a	Electricity generation in large combustion systems of public hard-lignite-fired power stations	11	13th BImSchV	DTKW	Public services	S	OEHBKW13	
3	Electricity generation in waste incineration systems of public power stations	11	17th BImSchV	DTKW	Public services	S	OEKW17	
4	Electricity generation in gas turbines of public power stations	11	TA Luft	GTKW	Public services	S	OEKWGT	
4a	Electricity generation in gas and steam turbine systems of public power stations	11	13th BImSchV / TA Luft	GuD	Public services	S	OEKWGUD	
5	Electricity generation in gas machines of public power stations	11	TA Luft	GMKW	Public services	S	OEKWGM	
6	Electricity generation in diesel motors of public power stations	11	TA Luft	DMKW	Public services	S	OEKWDM	
6a	Power generation from biogenic fuels	11	TA Luft / 1st BImSchV		Public services	S	OEKWBIO	no entry for the time being
22	Heat generation in large combustion systems of public power stations	15	13th BImSchV	DTKW	Public services	W	HEKW13	
22a	Heat generation in large combustion systems of public lignite-fired power stations (Kassel)	15	13th BImSchV	DTKW	Public services	W	HEBKW13	no entry for the time being
23	Heat generation in waste-incineration systems of public power stations	15	17th BImSchV	DTKW	Public services	W	HEKW17	
25	Heat generation in gas turbines of public power stations	15	TA Luft	GTKW	Public services	W	HEKWGT	
25a	Heat generation in gas and steam turbine systems of public power stations	15	13.BImSchV/TA Luft	GuD	Public services	W	HEKWGuD	
26	Heat generation in gas machines of public power stations	15	TA Luft	GMKW	Public services	W	HEKWGM	
27	Heat generation in diesel motors of public power stations	15	TA Luft	DMKW	Public services	W	HEKWDM	
28	Heat generation in large combustion systems of public district heat stations	16	13th BImSchV	FHW	Public services	W	FEHW13	
29	Heat generation in waste-incineration systems of public district heat stations	16	17th BImSchV	FHW	Public services	W	FEHW17	
30	Heat generation in TA Luft systems of public district heat stations	16	TA Luft	FHW	Public services	W	FEHWTA	

1) DTKW = steam turbine power stations, GTKW = gas turbine power stations, GT = gas turbines, GuD = gas and steam turbine power stations, GMKW = gas motor power stations, DMKW = diesel motor power stations, FHW = district heat stations, FA = combustion systems, PF = process furnaces

2) S = electricity generation , W = heat generation, K = power production (direct drive)

Table 11: Structure of the Balance of Emissions Causes – coal mining

No.	Process, fuel	EB line	Classification under emissions laws	Type of facility[1)]	Economic sector	SWK[2)]	File name	Remarks
Coal mining								
7	Electricity generation in large combustion systems of STEAG	12	13th BImSchV	DTKW	Coal mining / STEAG	S	STEA13	
8	Electricity generation in large combustion systems of other mine-pit power stations	12	13th BImSchV	DTKW	Other coal mining	S	ZEKW13	
8a	Electricity generation in large combustion systems of mine-pit power stations	12	13th BImSchV	DTKW	Other coal mining	S	GRKW13	
9	Electricity generation in gas turbines of mine and mine-pit power stations	12	TA Luft	GTKW	Coal mining	S	ZGKWGT	
10	Electricity generation in gas machines of mine and mine-pit power stations	12	TA Luft	GMKW	Coal mining	S	ZGKWGM	Assumption: natural gas and light heating oil are used solely in GTKW. For this reason, the file / line contains no entry. Cf. also Tab. 60
11	Electricity generation in diesel motors of mine and mine-pit power stations	12	TA Luft	DMKW	Coal mining	S	ZGKWDM	
32	Heat generation in large combustion systems of STEAG	40	13th BImSchV	DTKW	Coal mining / STEAG	W	UEST13	
33	Heat generation in large combustion systems other mine-pit power stations	40	13th BImSchV	DTKW	Other coal mining	W	UEZK13	
33a	Heat generation in large combustion systems of mine-pit power stations	40	13th BImSchV	DTKW	Other coal mining	W	UEGK13	
38	Heat generation in gas turbines of mine and mine-pit power stations	40	TA Luft	GTKW	Coal mining	W	UEKZGT	Fuel allocated completely to electricity generation
40	Heat generation in gas machines of mine and mine-pit power stations	40	TA Luft	GMKW	Coal mining	W	UEKZGT	Fuel allocated completely to electricity generation
41	Direct drive via diesel motors of mine and mine-pit power stations	40	TA Luft	DMKW	Coal mining	K	UEKZDM	
43	Production of hard-coal coke	40	TA Luft	PF	Coal mining	W	UEPFKO	
43a	Production of hard-coal coke (17th BImSchV)	40	17th BImSchV	PF	Coal mining	W	UEPFKO17	

1) DTKW = steam turbine power stations, GTKW = gas turbine power stations, GT = gas turbines, GuD = gas and steam turbine power stations, GMKW = gas motor power stations, DMKW = diesel motor power stations, FHW = district heat stations, FA = combustion systems, PF = process furnaces

2) S = electricity generation , W = heat generation, K = power production (direct drive)

Table 12: Structure of the Balance of Emissions Causes – other industrial power stations

No.	Process, fuel	EB line	Classification under emissions laws	Type of facility[1)]	Economic sector	SWK[2)]	File name	Remarks
Other industrial power stations								
12	Electricity generation in large combustion systems of DB power stations	12	13th BImSchV	DTKW	Deutsche Bahn AG (German Railways)	S	DBKW13	
14	Electricity generation in large combustion systems of other industrial power stations	12	13th BImSchV	DTKW	Other mining and manufacturing (not including VAW)	S	UIKW13	
14a	Electricity generation in large combustion systems of Vereingte Aluminium Werke (VAW), Bonn	12	13th BImSchV	DTKW	Vereinigte Aluminium Werke (VAW)	S	VAW13	
15	Electricity generation in waste incineration systems of other industrial power stations	12	17th BImSchV	DTKW	Other mining and manufacturing	S	UIKW17	
16	Heat generation in TA Luft systems of other industrial power stations	12	TA Luft	DTKW	Other mining and manufacturing	S	UIKWTA	
18	Electricity generation in gas turbines of other industrial power stations	12	TA Luft	GTKW	Other mining and manufacturing	S	UIKWGT	
19	Electricity generation in gas machines of other industrial power stations	12	TA Luft	GMKW	Other mining and manufacturing	S	UIKWGM	
21	Electricity generation in diesel motors of other industrial power stations	12	TA Luft	DMKW	Other mining and manufacturing	S	UIKWDM	
24	Heat generation in TA Luft systems of other industrial power stations (only production for feeding into public grid)	15	TA Luft	DTKW	Other mining and manufacturing	W	HEKWTA	For the old German Länder, heat generation in thermal power stations has been allocated completely to the 13th BImSchV
35	Heat generation in large combustion systems of other industrial power stations of the transformation sector	40	13th BImSchV	DTKW	Other energy producers	W	UEKI13	
37	Heat generation in TA Luft systems of industrial power stations of the transformation sector	40	TA Luft	DTKW	Other energy producers	W	UEKITA	No entry, since all power stations must be allocated to the 13th BImSchV
47	Heat generation in large combustion systems of industrial power stations of the manufacturing sector and other mining	60	13th BImSchV	DTKW	Other mining and manufacturing	W	INKW13	
48	Heat generation in waste-incineration systems of the manufacturing sector and other mining	60	17th BImSchV	DTKW	Other mining and manufacturing	W	INKW17	
50	Heat generation in TA Luft systems of industrial power stations of the manufacturing sector and other mining	60	TA Luft	DTKW	Other mining and manufacturing	W	INKWTA	
51	Heat generation in gas turbines of industrial power stations of the manufacturing sector and other mining	60	TA Luft	GTKW	Other mining and manufacturing	W	INKWGT	For the time being, fuel inputs allocated completely to electricity generation
52	Heat generation in gas machines of industrial power stations of the manufacturing sector and other mining	60	TA Luft	GMKW	Other mining and manufacturing	W	INKWGM	For the time being, fuel inputs allocated completely to electricity generation
53	Heat generation in diesel engines of industrial power stations of the manufacturing sector and other mining	60	TA Luft	DMKW	Other mining and manufacturing	W	INKWDM	For the time being, fuel inputs allocated completely to electricity generation

1) DTKW = steam turbine power stations, GTKW = gas turbine power stations, GT = gas turbines, GuD = gas and steam turbine power stations, GMKW = gas motor power stations, DMKW = diesel motor power stations, FHW = district heat stations, FA = combustion systems, PF = process furnaces 2) S = electricity generation , W = heat generation, K = power production (direct drive)

Table 13: Structure of the Balance of Emissions Causes – refineries, other energy producers, iron and steel industry

No.	Process, fuel	EB line	Classification under emissions laws	Type of facility[1)]	Economic sector	SWK[2)]	File name	Remarks
Refineries								
13	Electricity generation in large combustion systems of refinery power stations	12	13th BImSchV	DTKW	Petroleum processing	S	UIKR13	
17	Electricity generation in gas turbines of refinery power stations	12	TA Luft	GTKW	Petroleum processing	S	UIKRGT	
20	Electricity generation in diesel motors of refinery power stations	12	TA Luft	DMKW	Petroleum processing	S	UIKRDM	No entry; diesel fuel is allocated completely to Other mining and manufacturing (UIKWDM)
34	Heat generation in large combustion systems of refinery power stations	40	13th BImSchV	DTKW	Petroleum processing	W	UEKR13	
39	Heat generation in gas turbines of refinery power stations	40	TA Luft	GTKW	Petroleum processing	W	UEKRGT	Fuel allocated completely to electricity generation
42	Heat generation in diesel motors of refinery power stations	40	TA Luft	DMKW	Petroleum processing	W	UEKRDM	Is included in UEKZDM
44	Refinery process combustion (large combustion systems)	40	13th BImSchV	PF	Petroleum processing	W	UEPFRG	
44a	Process combustion in refineries (TA Luft installations)	40	TA Luft	PF	Petroleum processing	W	UEPFRT	
Other energy producers of the transformation sector								
31	Heat generation in large combustion systems (industrial boilers) of the other transformation sector	40	13th BImSchV	FA	Other energy producers	W	UEUM13	
36	Heat generation in TA Luft systems (industrial boilers) of the other transformation sector	40	TA Luft	FA	Other energy producers	W	UEUMTA	
Iron and steel industry								
54	Manufacturing of pig iron (process combustion)	60	TA Luft	Hochofen	Iron and steel industry	W	INPFHO	
55	Sinter production (process combustion)	60	TA Luft	Sinteranlagen	Iron and steel industry	W	INPFSI	

1) DTKW = steam turbine power stations, GTKW = gas turbine power stations, GT = gas turbines, GuD = gas and steam turbine power stations, GMKW = gas motor power stations, DMKW = diesel motor power stations, FHW = district heat stations, FA = combustion systems, PF = process furnaces

2) S = electricity generation , W = heat generation, K = power production (direct drive)

Table 14: Structure of the Balance of Emissions Causes – other tables

No.	Process, fuel	EB line	Classification under emissions laws	Type of facility[1]	Economic sector	SWK[2]	File name	Remarks
Other tables in the BEU structure								
36a	Gas turbines in natural-gas-compressor stations	33	TA Luft	GT	Gas industry	K	GVKOMP	
46	Heat generation in large combustion systems (industrial boilers) of the manufacturing sector and other mining	60	13th BImSchV	Steam / hot-water boilers	Other mining and manufacturing	W	INDU13	
49	Heat generation in TA Luft systems (industrial boilers) of other mining and manufacturing (process heat)	60	TA Luft	Steam / hot-water boilers	Other mining and manufacturing	W	INDUTAP	
49a	Heat generation in TA Luft systems (industrial boilers) of other mining and manufacturing (heating systems)	60	TA Luft	Steam / hot-water boilers	Other mining and manufacturing	W	INDUTAH	
53a	Heat generation in small combustion systems (industrial boilers) of the other mining and manufacturing sector (process heat)	60	1st BImSchV	Steam / hot-water boilers	Other mining and manufacturing	W	INDU01P	
53b	Heat generation in small combustion systems (industrial boilers) of the other mining and manufacturing sector (heating systems)	60	1st BImSchV	Steam / hot-water boilers	Other mining and manufacturing	W	INDU01H	
56	Production of Siemens-Martin steel (process combustion)	60	TA Luft	Siemens-Martin furnaces	Steel production	W	INPFSM	
57	Manufacturing of rolled steel (process combustion)	60	TA Luft	Production of rolled steel	Steel production	W	INPFWA	
58	Production of iron, steel and malleable cast iron (process combustion)	60	TA Luft	Foundries	Foundry industry	W	INPFGU	
59	Production of non-ferrous heavy metals (process combustion)	60	TA Luft	Foundries for non-ferrous metals	Non-ferrous-metal production	W	INPFNE	
60	Lime production (process combustion)	60	TA Luft	Lime ovens	Lime production	W	INPFKA	
61	Production of cement clinkers (process combustion)	60	TA Luft	Cement ovens	Cement production	W	INPFZK	
62	Glass production (process combustion)	60	TA Luft	Glass smelters	Glass production	W	INPFGL	
63	Sugar manufacturing (process combustion)	60	TA Luft	Sugar refineries	Sugar production	W	INPFZU	
64	Manufacturing of coarse ceramics (process combustion)	60	TA Luft	Kilns	Brick production	W	INPFZI	
65	Calcium carbide production (process combustion)	60	TA Luft	Kilns	Calcium carbid production	W	INPFCA	
66	Other process combustion	60	TA Luft	Process combustion	Other mining and manufacturing	W	INUEPF	
67	Heat generation in TA Luft systems in agricultural and horticultural operations	67	TA Luft	Steam / hot-water boilers	Agriculture	W	LAWITA	
68	Heat generation in small combustion systems in agricultural and horticultural operations	67	1st BImSchV	Steam / hot-water production systems	Agriculture	W	LAWI01	
69	Heat generation in TA Luft systems of other small consumers	67	TA Luft	Hot-water boilers	Small consumers	W	UEKVTA	
70	Heat generation in small combustion systems of other small consumers	67	1st BImSchV	Hot-water boilers	Small consumers	W	UEKV01	
71	Heat generation in TA Luft systems of military agencies	67	TA Luft	Hot-water boilers	Military agencies	W	MILITA	
72	Heat generation in small combustion systems of military agencies	67	1st BImSchV	Hot-water boilers	Military agencies	W	MILI01	
73	Heat generation in small combustion systems of households	66	1st BImSchV	Heat producing systems	Households	W	HAUS01	

1) GT = Gas turbines

2) S = electricity generation , W = heat generation, K = power production (direct drive)

Table 15: List of abbreviations for structural elements in the Central Database of Emissions (CSE) and the Balance of Emissions Causes (BEU)

AW HM DEPONI	Landfilled household waste, municipal waste
AW KS ABWASS	Sewage sludge produced in wastewater treatment
AW KS BEHAND	Treatment of sewage sludge
AW KS DEPONI	Landfilled sewage sludge
AW KS LANDWI	Spread sewage sludge (in agriculture)
AW NE ABWASS	Wastewater amount, N-eliminated
DBKW13	Electricity generation in large combustion systems of DB power stations
FEHW13	Heat generation in large combustion systems of public district heat stations
FEHW17	Heat generation in medium-sized combustion systems of public district heat stations
FEHWTA	Heat generation in TA Luft systems of public district heat stations
GRKW13	Electricity generation in large combustion systems of mine-pit power stations
GRKW17	Electricity generation in waste incineration systems of mine-pit power stations
GV AN E/ EÖG	Natural-gas use by households and small consumers: Natural gas / petroleum gas
GV AN SG	City-gas use by households and small consumers: Coking plants and city gas
GV AU E/ EÖG	processing of natural gas and petroleum gas: total amount processed
GV AU SG	City-gas processing: Coking plants and city gas
GV EZ HDKUÜ	High-pressure natural gas network made from plastic / other
GV EZ HDS/ DG	High-pressure natural-gas network made from steel / ductile cast
GV EZ MDGG	Medium-pressure natural-gas network made from gray-cast iron
GV EZ MDKUÜ	Medium-pressure natural-gas network made from plastic / other
GV EZ MDS/ DG	Medium-pressure natural-gas network made from steel / ductile cast
GV EZ NDGG	Low-pressure natural-gas network made from gray-cast iron
GV EZ NDKUÜ	Low-pressure natural gas network made from plastic / other
GV EZ NDS/ DG	Low-pressure natural-gas network made from steel / ductile cast
GV FÖ BERGW	Decommissioned mines: CH4 estimation
GV FÖ BK	Lignite mining: total amount processed
GV FÖ EG	Natural-gas extraction: total amount processed
GV FÖ EÖ	Petroleum extraction: total amount processed
GV FÖ GRUGAS	Pit gas
GV FÖ SK	Hard-coal mining: total amount processed
GV LA SK	Hard-coal storage: total amount processed
GV SZ HDKUÜ	High-pressure city-gas network made from plastic / other
GV SZ HDS/ DG	High-pressure city-gas network made from steel / ductile cast
GV SZ MDGG	Medium-pressure city-gas network made from gray-cast iron
GV SZ MDKUÜ	Medium-pressure city-gas network made from plastic / other
GV SZ MDS/ DG	Medium-pressure city-gas network made from steel / ductile cast
GV SZ NDGG	Low-pressure city-gas network made from gray-cast iron
GV SZ NDKUÜ	Low-pressure city-gas network made from plastic / other
GV SZ NDS/DG	Low-pressure city-gas network made from steel / ductile cast
GV TS E/ EÖG	Long-distance transport and storage of natural gas: Natural gas, petroleum gas
GV VE OK	Distribution of gasoline, total consumption
GVKOMP	Gas turbines in natural-gas-compressor stations
HAUS01	Heat generation in small combustion systems of households
HEKW13	Heat generation in large combustion systems of public power stations
HEKW17	Heat generation in medium-sized combustion systems of public power stations
HEKWDM	Heat generation in diesel motors of public power stations
HEKWGM	Heat generation in gas machines of public power stations
HEKWGT	Heat generation in gas turbines of public power stations
HEKWTA	Heat generation in TA Luft systems of other industrial power stations (only production for feeding into public grid)
INDU01	Heat generation in small combustion systems (industrial boilers) of other mining and manufacturing (heating systems)
INDU01P	Heat generation in small combustion systems (industrial boilers) of other mining and manufacturing (production heat)
INDU13	Heat generation in large combustion systems (industrial boilers) of other mining and manufacturing
INDUTA	Heat generation in TA Luft systems (industrial boilers) of other mining and manufacturing
INDUTAH	Heat generation in TA Luft systems (industrial boilers) of other mining and manufacturing (heating systems)
INDUTAP	Heat generation in TA Luft systems (industrial boilers) of other mining and manufacturing (production heat)
INKW13	Heat generation in large combustion systems of industrial power stations of other mining and manufacturing
INKW17	Heat generation in waste incineration systems of industrial power stations of other mining and manufacturing
INKWDM	Heat generation in diesel motors of industrial power stations of other mining and manufacturing
INKWGM	Heat generation in gas machines of industrial power stations of other mining and manufacturing
INKWGT	Heat generation in gas turbines of industrial power stations of other mining and manufacturing
NKWTA	Heat generation in TA Luft systems of industrial power stations of other mining and manufacturing
INPFCA	Calcium carbide production (process combustion)
INPFGL	Glass production (process combustion)
INPFGU	Manufacturing of iron, steel and malleable cast iron (process combustion)
INPFHO	Manufacturing of pig iron (process combustion)
INPFKA	Lime production (process combustion)
INPFNE	Production of non-ferrous heavy metals (process combustion)
INPFSI	Sinter production (process combustion)
INPFSM	Production of Siemens-Martin steel (process combustion)
INPFWA	Manufacturing of rolled steel (process combustion)
INPFZE	Cement production (process combustion)
INPFZI	Manufacturing of coarse ceramics (process combustion)
INPFZU	Sugar manufacturing (process combustion)
INUEPF	Other process combustion
IP CI ADIPIN	Adipic acid production
IP CI CAC2	Calcium-carbide production
IP CI DÜNGEM	Fertiliser production
IP CI FERROL	Production of ferroalloys
IP CI H2SO4	Sulphuric acid production, chemical industry
IP CI HNO3	Nitric acid production
IP CI N2O	Nitrous oxide production
IP CI NDÜNGE	Nitrogen-containing fertilisers (mononutrient fertilisers)
IP CI NH3	Ammonia production: Synthesis of NH3 based on N
IP CI ORGPRO	Organic product emissions

Table 15: Con'd

IP CI RUSS	Soot production
IP CI SODA	Soda production based on NA2CO3
IP CI TIO2	Titanium-dioxide production
IP EN BKBR	Lignite briquetting: Briquette production
IP EN BKSTAU	Lignite-dust processing Production of coal dust and dry coal
IP EN BTTKO	Low-temperature lignite coking: Coke production
IP EN EGABFA	Flaring of natural gas: amount flared
IP EN RAFEIN	Refinery operations: inputs of crude oil and products
IP EN SEG	Desulphurisation of natural gas: Sulphur production
IP EN SKAU	Hard-coal processing: total amount processed
IP EN SKBR	Hard-coal briquetting: Briquette production
IP EN SRAF	Desulphurisation in refineries: Sulphur production
IP ES ELST	Steel production: Electric steel production
IP ES ESTG	Foundries: iron and steel casting (including malleable casting)
IP ES OXST	Steel production: Blown steel production
IP ES ROHFE	Blast furnaces: pig iron production
IP ES SINTER	Sintering plants: sinter production
IP ES SKKOKS	Coking plants: Hard-coal coke production
IP ES SMST	Steel production: Siemens-Martin steel production
IP ES THST	Steel production: Thomas-steel production
IP ES WALZST	Steel production: rolled steel production
IP NE BLEI	lead production: refined lead
IP NE H2SO4	Sulphuric acid production, metallurgical works
IP NE HÜALU	Aluminium production: primary aluminium
IP NE KUPFER	Copper production: Electrolyte copper, fire-refined Copper
IP NE UMALU	Aluminium production: Resmelted aluminium
IP NE ZINK	Zinc production: Primary and resmelted zinc
IP NE ZNSTG	Galvanising: galvanised products
IP NF SPANPL	Particle-board production
IP NF ZELLST	Pulp processing: Paper pulp (including fine and synthetic fibre pulp)
IP NG BIER	Beer production
IP NG BROT	Bread production: Consumption of bread-grain flour
IP NG SPIRIT	Spirits production
IP NG WEIN	Wine production
IP NG ZUCKER	Sugar production
IP SE BITUMG	Asphalt production
IP SE GLAS	Glass production_ Bottle, flat, float glass
IP SE GROBKE	Coarse ceramics: bricks, roof tiles, formed fireproof products
IP SE KALIS	Potassium salt production
IP SE KALK	Lime burning: limestone and calcite, burned; dolomite, burned or sintered
IP SE ÜBSALZ	Other salt production: Rock and metallurgical salt, salt-works salt
IP SE ZEMENT	Cement plants: Cement production
IP SE ZEMKLI	Cement plants: Cement clinker production
LAWI01	Heat generation in small combustion systems in agricultural and horticultural operations
LAWITA	Heat generation in TA Luft systems in agricultural and horticultural operations
MILI01	Heat generation in small combustion systems of military agencies
MILITA	Heat generation in TA Luft systems of military agencies
OEBK13	Electricity generation in large combustion systems of public crude-lignite-fired power stations
OEHBKW13	Electricity generation in large combustion systems of public hard-lignite-fired power stations
OEKW13	Electricity generation in large combustion systems of public power stations
OEKW17	Electricity generation in waste incineration systems of public power stations
OEKWDM	Electricity generation in diesel motors of public power stations
OEKWGM	Electricity generation in gas machines of public power stations
OEKWGT	Electricity generation in gas turbines of public power stations
PV LM EF+CHR	Degreasing, dry-cleaning: Emissions
PV LM H+ACHP	Production and use of chemical products: Emissions
PV LM LACK	Lacquering: Emissions
PV LM ÜBRLM	Other solvent use: Emissions
PV ÜB N20	Nitrous oxide: Emissions
PV ÜB NH3SCR	SCR systems: smothered
SNAP 10 01 00	Cultures with fertilisers
SNAP 10 02 00	Cultures without fertilisers
SNAP 10 04 01	Enteric fermentation (dairy cows)
SNAP 10 04 02	Enteric fermentation (other cattle)
SNAP 10 04 03	Enteric fermentation (sheep)
SNAP 10 04 05	Enteric fermentation (horses)
SNAP 10 04 08	Enteric fermentation (laying hens)
SNAP 10 04 09	Enteric fermentation (broilers)
SNAP 10 04 10	Enteric fermentation (poultry)
SNAP 10 05 00	Manure management regarding organic compounds
SNAP 10 05 01	Manure management, dairy cows
SNAP 10 05 02	Manure management, other cattle
SNAP 10 05 05	Manure management, other sheep
SNAP 10 05 06	Manure management, other horses
SNAP 10 05 07	Manure management, laying hens
SNAP 10 05 08	Manure management, broilers
SNAP 10 05 09	Manure management, other poultry
STEA13	Electricity generation in large combustion systems of STEAG
SV BUS KOAB	Conventional buses, fuel consumption on autobahn
SV BUS KOAO	Conventional buses, fuel consumption outside of municipalities
SV BUS KOIO	Conventional buses, fuel consumption in municipalities
SV BUS MTAB	Buses with emissions-reduction equipment, fuel consumption on autobahn
SV BUS MTAO	Buses with emissions-reduction equipment, fuel consumption outside of municipalities
SV BUS MTIO	Buses with emissions-reduction equipment, fuel consumption in municipalities
SV LNFD KOAB	Conventional light commercial diesel vehicles, autobahn
SV LNFD KOAO	Conventional light commercial diesel vehicles, outside of municipalities
SV LNFD KOIO	Conventional light commercial diesel vehicles, municipalities
SV LNFD MTAB	Light diesel commercial vehicles with emissions-reduction equipment, autobahn
SV LNFD MTAO	Light diesel commercial vehicles with emissions-reduction equipment, outside of municipalities
SV LNFD MTIO	Light diesel commercial vehicles with emissions-reduction equipment, in municipalities
SV LNFO KOAB	Conventional light commercial gasoline-engine vehicles, autobahn
SV LNFO KOAO	Conventional light commercial gasoline-engine vehicles, outside of municipalities

Table 15: Con'd

SV LNFO KOIO	Conventional light commercial gasoline-engine vehicles, municipalities
SV LNFO KOVD	Evaporation: Conventional gasoline-engine automobiles, fuel consumption in municipalities
SV LNFO MTAB	Light gasoline-engine commercial vehicles with emissions-reduction equipment, autobahn
SV LNFO MTAO	Light gasoline-engine commercial vehicles with emissions-reduction equipment, outside of municipalities
SV LNFO MTIO	Light gasoline-engine commercial vehicles with emissions-reduction equipment, in municipalities
SV LNFO MTVD	Evaporation: Light gasoline-engine commercial vehicles with emissions-reduction equipment, consumption in municipalities
SV MOPED VD	Evaporation: Mopeds, overall consumption
SV MOPED	Mopeds, overall consumption
SV MRAD KOAB	Conventional motorcycles, fuel consumption on autobahn
SV MRAD KOAO	Conventional motorcycles, fuel consumption outside of municipalities
SV MRAD KOIO	Conventional motorcycles, fuel consumption in municipalities
SV MRAD KOVD	Evaporation, motorcycles, fuel consumption in municipalities
SV MRAD MTAB	Motorcycles with emissions-reduction equipment, fuel consumption on autobahn
SV MRAD MTAO	Motorcycles with emissions-reduction equipment, fuel consumption outside of municipalities
SV MRAD MTIO	Motorcycles with emissions-reduction equipment, fuel consumption in municipalities
SV MRAD MTVD	Evaporation, motorcycles with emissions-reduction equipment, fuel consumption in municipalities
SV MRAD VD	Evaporation, motorcycles, overall fuel consumption
SV PKWD KOAB	Conventional diesel automobiles, autobahn
SV PKWD KOAO	Conventional diesel automobiles, outside of municipalities
SV PKWD KOIO	Conventional diesel automobiles, in municipalities
SV PKWD MTAB	Diesel automobiles with emissions-reduction equipment, autobahn
SV PKWD MTAO	Diesel automobiles with emissions-reduction equipment, outside of municipalities
SV PKWD MTIO	Diesel automobiles with emissions-reduction equipment, in municipalities
SV PKWO KOAB	Conventional gasoline-engine automobiles, autobahn
SV PKWO KOAO	Conventional gasoline-engine automobiles, outside of municipalities
SV PKWO KOIO	Conventional gasoline-engine automobiles, in municipalities
SV PKWO KOVD	Evaporation: Conventional gasoline-engine automobiles, fuel consumption in municipalities
SV PKWO MTAB	Gasoline-engine automobiles with emissions-reduction equipment, autobahn
SV PKWO MTAO	Gasoline-engine automobiles with emissions-reduction equipment, outside of municipalities
SV PKWO MTIO	Gasoline-engine automobiles with emissions-reduction equipment, in municipalities
SV PKWO MTVD	Evaporation: Gasoline-engine automobiles with emissions-reduction equipment, fuel consumption in municipalities
SV SNF KOAB	Conventional heavy commercial vehicles, fuel consumption autobahn
SV SNF KOAO	Conventional heavy commercial vehicles, fuel consumption outside of municipalities
SV SNF KOIO	Conventional heavy commercial vehicles, fuel consumption in municipalities
SV SNF MTAB	heavy commercial vehicles with emissions-reduction equipment, fuel consumption on autobahn
SV SNF MTAO	Heavy commercial vehicles with emissions-reduction equipment, fuel consumption outside of municipalities
SV SNF MTIO	heavy commercial vehicles with emissions-reduction equipment, fuel consumption in municipalities
UEGK13	Heat generation in large combustion systems of mine-pit power stations
UEKB13	Heat generation in large combustion systems of power stations of the lignite-mining sector
UEKI13	Heat generation in large combustion systems of other industrial power stations in the transformation sector
UEKITA	Heat generation in TA Luft systems of industrial power stations of the transformation sector
UEKR13	Heat generation in large combustion systems of refinery power stations
UEKRDM	Heat generation in diesel motors of refinery power stations
UEKRGT	Heat generation in gas turbines of refinery power stations
UEKS13	Heat generation in large combustion systems of other power stations of the hard-coal mining sector
UEKV01	Heat generation in small combustion systems of other small consumers
UEKVTA	Heat generation in TA Luft systems of other small consumers
UEKZDM	Direct drive via diesel motors of mine and mine-pit power stations
UEKZGM	Heat generation in gas machines of mine and mine-pit power stations
UEKZGT	Heat generation in gas turbines of mine and mine-pit power stations
UEPFKO	Process combustion in refineries (large combustion systems)
UEPFRG	Production of hard-coal coke
UEPFRT	Process combustion in refineries (TA Luft installations)
UEST13	Heat generation in large combustion systems of STEAG
UEUEPF	Other process combustion (only new German Länder)
UEUM13	Heat generation in large combustion systems (industrial boilers) of the other transformation sector
UEUMTA	Heat generation in TA Luft systems (industrial boilers) of the other transformation sector
UEZK13	Heat generation in large combustion systems other mine-pit power stations
UIKR13	Electricity generation in large combustion systems of refinery power stations
UIKRDM	Electricity generation in diesel motors of refinery power stations
UIKRGT	Electricity generation in gas turbines of refinery power stations
UIKW13	Electricity generation in large combustion systems of other industrial power stations
UIKW17	Electricity generation in waste incineration systems of other industrial power stations
UIKWDM	Electricity generation in diesel motors of other industrial power stations
UIKWGM	Electricity generation in gas machines of other industrial power stations
UIKWGT	Electricity generation in gas turbines of other industrial power stations
UIKWTA	Heat generation in TA Luft systems of other industrial power stations
UVBAWI	Construction-related transport
UVHAUS	Residential, mobile sources
UVHBFI	Blue-water fishing (international)
UVHBIN	Navigation
UVKBFI	Coastal and inland fisheries
UVLAWI	Agricultural transport

Table 15: Con'd

UVLUMI	Military air transport
UVLZIN	Civil air transport (international)
UVLZNA	Civil air transport (national)
UVMILI	Military transport
UVSCHI	Railway transport
UVUEKB	Coastal and inland navigation
ZEKW13	Electricity generation in large combustion systems of other mine-pit power stations
ZGBK13	Electricity generation in large combustion systems of power stations of the lignite-mining sector
ZGKWDM	Electricity generation in diesel motors of mine and mine-pit power stations
ZGKWGM	Electricity generation in gas machines of mine and mine-pit power stations
ZGKWGT	Electricity generation in gas turbines of mine and mine-pit power stations
ZGSK13	Electricity generation in large combustion systems of other power stations of the hard-coal mining sector

The stationary combustion-related energy activities are taken from the BEU, entered into the CSE and then properly aggregated, for the various source categories, pursuant to CRF. The road-traffic data comes primarily from the TREMOD database.

3.1.1 Public electricity and heat production (1.A.1.a)

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

CRF 1.A.1.a						
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
All Fuels	l / t	CO_2	26,03 %	30,25 %	rising
All Fuels	- / t	N_2O	0,29 %	0,18 %	falling

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	CS	CS	NO	NO	NO	CS	CS	CS	CS	CS
EF uncertainties in %	< 3	+/-50	-	-	-	+/-50				
Distribution of uncertainties	T	U	-	-	-	U				
Method of EF determination	CS	Tier 2	-	-	-	Tier 2				

Note: See the "Declaration regarding introductory information tables", at the beginning of the NIR, for further information about these tables.

The source category Public electricity and heat production is a key category, in terms of emissions levels and trend, for CO_2 emissions from solid, gaseous and liquid fuels. The relevant solid fuels are also a key category, in terms of emissions levels, for N_2O emissions.

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 Environmental Agency. The numbers themselves are based on a personal communication from an expert.

In the public electricity supply sector, the net bottleneck capacity of installed electrical plants that burn fossil fuels is about 67 GW. Of this capacity, 45 GW is fired with hard coal and lignite. In the year 2004, all of the plants together produced some 308 TWh of electrical power, accounting for 58 % of public electricity generation.

Thermal power stations contribute an electrical output of 11 GW to the public supply. Their maximum thermal capacity totals 23 GW. In the year 2003, they produced around 30 TWh of electricity and 491 PJ of district heat. District heating generation is supplemented by district heat plants with a thermal output of 22 GW. These plants supplied just under 66 PJ to the public district heat network. 72 % of district heat plants' output was produced using natural gas, 7 % was produced using hard coal and lignite, 11 % was produced using waste fuels, and 10% was produced using petroleum products.

Under source category 1.A.1.a, Public electricity and heat production, the CSE includes district heat plants and electricity and heat production of public power stations.

Figure 17: Structural allocation, 1.A.1a Public electricity and heat production

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

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

Fuel use in power stations for the public supply is stated in line 11 (public thermal power stations) and line 15 (CHP stations) of the energy balance (AGEB, 2003), while the fuel use in district heat stations is reported in line 16.

Table 10 through Table 14 show how the fuel inputs in the "*Balance of Emission Causes*" (BEU) model are structured. This structure makes it possible to provide a complete picture of the sector. The activity rates for 1990 for the new German Länder were revised and substantiated. The relevant methods and results are described in Annex 3 (Chapter 14.1.1).

The structural elements "Electricity and heat production in large combustion systems of public power stations" were revised with the aid of improved data for the old German Länder (1990-1994). In the process, the raw-lignite figures were broken down by the relevant mining districts (Rheinland, Hessen and Helmstedt). Very little raw lignite is mined in the Bayern district, and the amount that is mined is not used for the public electricity supply. Allocation of activity rates to specific mining districts has increased overall accuracy by leading to district-specific CO_2 emission factors that reflect the variances in raw-lignite composition from district to district.

Availability of new statistics has now made it possible to list gas and steam turbine power stations separately, for the first time, for the period since 2003.

Additional changes in methods have resulted via revision of the structural elements "Electricity and heat production in waste-incineration facilities of public power stations" and "Heat production in waste-incineration facilities of public district heating stations". In the case of energy production in waste-incineration facilities, the Energy Balance figures diverge from those in the Federal Statistical Office's waste statistics (DESTATIS, FS19 R1), with the latter source showing considerably higher values. Presumably, the waste statistics use more realistic assumptions for determining fuel input from waste (in the present case, household / municipal waste) than the Energy Balance does. For this reason, the discrepancies between the Energy Balance figures and those in specialised series 19 (Fachserie 19; DESTATIS, FS19 R1) are compensated for via inclusion of non- Energy Balance lines. Overall, this procedure increases the activity rates for household / municipal waste as of 1990.

As of the NIR 2006, the fossil and biogenic fractions of household / municipal waste are listed separately, in a ratio of 50/50.

The underlying data for the emission factors used 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 - 2004 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 3.1.2, 3.1.3, 3.1.4.6 and 3.1.5.5, where the factors include power stations, gas turbines or boilers for generation of steam and hot/warm water. The research project was carried out by the Franco-German Institute for Environmental Research (Deutsch-Französischen 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 plants in Germany that are subject to licensing requirements, and to do so for the years 1995, 2000 and 2010. This process consists primarily of analyzing and characterising the relevant emitter structures, and the pertinent emission factors, for the year 1995, and then of updating the data for the years 2000 and 2010. This procedure systematically determines emission factors for the substances SO_2, NO_X, CO, NMVOC, dust and N_2O. The process 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 is also compiled; these other substances include PAH, PCDD/F, As and Cd for combustion plants subject to licensing requirements, and CH_4 for gas turbines and combustion plants under the TA Luft that are subject to licensing requirements. Annex 3 (Chapter 14.1.2.1) discusses the procedure used in the research project.

For gas and steam turbine power stations, which are now listed for the first time, the emission factors of gas turbines of public power stations were used, in unchanged form.

In Germany, N_2O is monitored only in exceptional cases; for this reason, no relevant data from regular measurements is available. On the other hand, relevant emissions behaviour in combustion of hard coal and lignite, especially in fluidised-bed combustion, has been specifically studied over the past 15 years. For this reason, enough measurement data was available to permit systematic survey of N_2O emission factors in the research project. The relevant technological emission factors for large combustion plants, as determined in the research project, are summarised in 14.1.2.1. These factors were used as a basis for calculating the source-category-specific emission factors for the CSE.

Table 16: Technological emission factors for nitrous oxide from large combustion plants

Fuel / combustion technology	**N_2O emission factor (1995 - 2010) [kg/TJ]**
Hard coal / fluidised bed	20
Hard coal / other combustion methods	4
Lignite / fluidised bed	8
Lignite / dry-dust combustion, in the new Länder	3,2
Lignite / other combustion methods	3,5
Liquid fuels	1
Gaseous fuels	0,5

The data presented in the following table, taken from from the research project RENTZ et al (2002), served as the basis for systems < 50 MW furnace thermal output. The relevant median figures are shown in brackets.

Table 17: Technological emission factors for nitrous oxide from systems < 50 MW furnace thermal output

Fuel		**Technology**	**Output**	**Federal Länder**	**N_2O-E factor / median [kg/TJ]**
Hard coal		Grate combustion	< 5 MW	/	2,5 - 5,2 [3,9]
			≥ 5 MW	ABL	2,5 - 5,2 [3,9]
			≥ 5 MW	NBL	2,5 - 5,2 [3,9]
		Furnace-shell combustion	< 5 MW	ABL	2,5 - 5,2 [3,9]
			< 5 MW	NBL	2,5 - 5,2 [3,9]
			≥ 5 MW	/	2,5 - 5,2 [3,9]
		Fluidised-bed combustion	< 5 MW	/	25 - 40 [36]
			≥ 5 MW	/	2 - 170 [47]
Lignite	- dust	Dust combustion	≥ 5 MW	NBL	[3,2]
	- briquette	n.i.	< 5 MW	NBL	0,4 - 3,7 [2,1]
	crude	n.i.	< 5 MW	NBL	0,4 - 3,7 [2,1]
			≥ 5 MW	ABL	0,4 - 3,7 [2,1]
			≥ 5 MW	NBL	0,4 - 3,7 [2,1]
		Fluidised-bed combustion	≥ 5 MW	/	40 - 50 [45]
Heavy heating oil		n.i.	/	ABL	2 - 4 [3]
			/	NBL	2 - 4 [3]
Light heating oil		n.i.	≥ 20 MW	/	0,6 - 1,5 [1,1]
Natural gas		n.i.	≥ 10 MW	/	0,3 - 1,5 [0,9]

n.i. not included
ABL Old German Länder
NBL New German Länder

In the framework of the research project "limestone balance" ("Kalksteinbilanz"; UBA 2006, FKZ 20541217/02), data for CO_2 emissions flue-gas desulphurisation were determined for the source category Electricity and heat production in public power stations (reference to 4.1.3). 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 sulphur content of the fuels in question and to the economic value of the resulting residual substances (plaster). In the electricity-generation sector, the limestone-washing procedure represents the current state of the art. In terms of installed output, some 87 % of all power stations in Germany use this process (Rentz et al. 2002b).

The amounts of limestone used in power stations are determined on the basis of plaster production. In stoichiometric calculation of limestone use in the limestone-washing process, the relevant relationship for the gross chemical reaction,

$CaCO_3 + SO_2 + 1/2O_2 + H_2O ==> CaSO_4.2H_2O + CO_2$

is used as a basis for the process (complete conversion). The input-limestone amounts calculated in this manner were compared with the results obtained via another method of determination. Input-limestone amounts can also be derived from the figures for sulphur content of the fuels used in in power stations, and from the resulting sulphur-dioxide emissions, using the above reaction equation. The degree of desulphurisation (achieved through desulphurisation equipment) can be derived by subtracting the actual SO_2 emissions, as listed in environmental reporting, from the computed emissions. The degree of desulphurisation can then be converted into limestone input. This method shows the same basic trend: Limestone inputs increase drastically in the time series. This development is in keeping with increasing retrofitting of power stations with efficient flue-gas desulphurisation equipment, in the 1990s.

Due to the differences in calculation procedures involved, and to the fact that certain technical details remain to be clarified, the inventory was supplemented using the most conservative project data. The largest limestone input determined for flue-gas desulphurisation plants in the base year was 2.1 million tonnes of limestone. The most reliable figure for 2004 was 4.0 million tonnes of limestone. At the project's current progress level, no consistent time series can be generated for this conservative approach. As a result, linear interpolation was carried out between the basic data points, and the stoichiometric limestone-emission factor (identical with the IPCC default value) was used for emissions calculation. This resulted in the following CO_2 emissions:

Table 18: CO_2 emissions from flue-gas desulphurisation in public power stations

Structural element	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[Gg]														
REA (CaCO3) in public power stations	932	991	1.051	1.110	1.170	1.229	1.288	1.348	1.407	1.467	1.526	1.585	1.645	1.704	1.764

Source: Calculations from the "limestone balance" project ("Kalksteinbilanz";UBA 2006, FKZ 20541217/02)

In the inventory, these CO_2 emissions were assigned to emissions from use of solid fuels, because such use is the reason behind the flue-gas desulphurisation plants and the CO_2 emissions.

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

Research project 202 42 266 (UBA, 2004), aimed at implementing the IPCC-GPG requirements (2000) in inventory preparation, systematically determined the pertinent uncertainties (cf. Chap. 13.5.2).

For the first time, uncertainties were also determined for the activity rates (research project 20441132, UBA). The method for determining the uncertainties is described in Annex 2, Chapter 13.7.

Revision of energy data for the new German Länder for the base year, 1990, has produced some inconsistencies in the time series for the subsequent years 1991-1994. Additional aspects of time-series consistency for the energy data are discussed in Chapter 13.6.

The uncertainty of the determined emission factors has been evaluated in the framework of the DFIU research project described in Chapter 3.1.1.2 and in Annex 3, Chapter 14.1.2.1.

The activity rate for limestone use in flue-gas desulphurisation plants is still subject to considerable uncertainty.

3.1.1.3.1 Methods for determining uncertainties of emission factors

The uncertainties in emission data result from several different factors. These include *precision*, i.e. chance and systematic errors in the framework of emission measurement and *completeness* of the database with regard to lacking 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 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 does not suffice for quantification. A sample explanation is provided in Annex 3, in Chapter 14.1.2.2.

3.1.1.3.2 Result for N_2O

Individual evaluations of the uncertainties in N_2O emission factors, produced in the research project (RENTZ et al, 2002), are included in the Excel tables for transfer of emission factors into the Federal Environmental Agency's CSE database; for power stations, the evaluations are also described in the final report. The great majority of values for relative uncertainty lie in the range between 0.6 and 0.9. As part of an experts' assessment, carried out by the research customer, pursuant to Tier 1 IPCC-GPG (2000: Chapter 6), an upper boundary of +/- 50 % was given for the percentage uncertainty in 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: Kapitel 6, S. 6.14); in the process, uniform distribution of uncertainties is assumed – in keeping with the calculation method selected.

3.1.1.3.3 Result for CH_4

Combustion plants in Germany are not subject to monitoring of CH_4 emissions; for this reason, no systematic measurement data is available in this area. Consequently, individual items of data 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 source categories treated by the project (cf. Chapter 3.1.1.2). The individual CH_4 emission factors, as determined in the research project (RENTZ et al, 2002), are summarised in Annex 0. Previously, the factors listed there, for hard coal fired in combustion plants < 50 MW (mean value for D: 3.35 kg/TJ), and for light heating oil and natural gas fired in gas turbines, were used in the CSE. Review and adoption of the project's remaining proposals are still pending (cf. Chapter 3.1.1.4). For these fuels, the existing emission factors in the CSE are used without change (solid fuels: 1.5 kg/TJ; liquid fuels: 3.5 kg/TJ; and gaseous fuels: 0.3 kg/TJ).

As part of an experts' assessment carried out by the research customer, pursuant to Tier 1 of the IPCC-GPG (2000: Chapter 6), an upper limit of +/- 50 % was estimated for the percentage uncertainty in source category 1.A.1.a (as well as in source categories 1.A.1.b, 1.A.1.c and 1.A.2f / all other); in the process, a uniform distribution of uncertainties is assumed – as was the case for N_2O.

3.1.1.3.4 Time-series consistency of emission factors

In the framework of the aforementioned research project (RENTZ et al 2002), the emission factors for N_2O were determined for 1995 (reference year) and then extrapolated, on this basis, for 2000 and 2010. With this approach, no changes result for most of these emission factors for the period from 1995 to 2004. The N_2O emission factors were forecast to decrease slightly only in the area of use of gas turbines (natural gas, light heating oil). This is a secondary effect of the higher mean gas-turbine-intake temperatures used in modern gas turbines in order to increase efficiency. These changes have no significant effect, however, on levels of total N_2O emissions in the CRF area under consideration.

The time series for N_2O between 1995 and 2004 were reviewed in this light and assessed as consistent overall. The time series of CH_4 emission factors for 1995 to 2004 were also reviewed and assessed as internally consistent.

Source-specific review of N_2O and CH_4 emission factors with regard to consistency with the values as of 1995 remains to be carried out for the period from 1990 to 1994. This review is currently being carried out, taking account of the results of quality-assurance measures from Chapter 3.1.1.4 in the framework of a research project described in Chapter 3.1.1.3.2. Changed values are to be included in the inventory as soon as possible.

3.1.1.4 Source-specific quality assurance / control and verification (1.A.1.a)

For reporting, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents.

Since the inventories, in general, are based on the energy balances for Germany prepared by the Working Group on Energy Balances (AGEB, 2003) – whose quality-assurance system is currently not available – quality assurance, quality control and verification of energy inputs are carried out by reviewing the energy balance for completeness and plausibility. This procedure leads to re-allocations of fuel-use amounts within the energy balance, as well as to addition of energy inputs not listed in the energy balance – such as firewood use in the source categories residential, commercial/institutional and commerce, trade and services (cf. Chapters 13.3, 13.5.1, 13.5.2, 13.6.1, 13.8, 3.1.12).

General measures for assuring the quality of emission factors for combustion plants, as used in the framework of a research project (RENTZ et al, 2002), are outlined in the methods description in Annex 3, Chapter 14.1.2.1 (after Figure 70). Their results were reported in the NIR 2005. In the past year, correction of N_2O emission factors for hard-coal-fired public power stations – cf. NIR 2005, Chapter 3.1.1.3.4 – was completed with the help of the previously lacking interpolation for the years 1996 through 1999 and 2001 through 2010. This has has eliminated the "outlier" found in the Synthesis and Assessment Report 2004, part II. A number of additional quality assurance measures were also carried out. These included closing of gaps in the area of industrial power stations, where such stations supply part of their usable heat to the public district heating system. In addition, a number of individual values for the years 2001 and 2002 were corrected (previously, the value for 2000 had been adopted for those years); now, as in the procedure for all other time series, the values for these years have been obtained via linear interpolation between the values for 2000 and the projected values for 2010. (cf. Chapter 3.1.1.2).

3.1.1.5 Source-specific recalculations (1.A.1.a)

Source-specific recalculations for energy data have been carried out to account for data updates in the energy balance and for improvements in methods. The methodological improvements were made in close connection with the methods documentation for the energy sector called for in the review report for 2003 (FCCC, 2003: p. 3, sub-point 8); the relevant methods documentation has been improved for the NIR 2004, but it has not yet been completed. Recalculations can thus be documented only on the basis of this methodological documentation – i.e. in the 2007 report.

With the emissions data for N_2O and CH_4, the relevant recalculations have been completed for the work described in Chapter 3.1.1.4 (correction of emission factors, and closing of gaps).

CO_2 emissions from limestone use in flue-gas desulphurisation plants have been reported for the first time.

3.1.1.6 Planned improvements (source-specific) (1.A.1.a)

The following improvements are planned in the area of modelling of activity rates:

- For the 2004 reporting year, the energy inputs for public electricity and heat production in gas and steam power stations and gas-fired machines, including inputs of natural gas, landfill gas, wastewater-treatment gas and light heating oil, were modelled in keeping with a new method and with data of the Federal Statistical Office (research project 204 41 132, UBA, in preparation). In the Energy Balance system, this work affects entries for light heating oil, natural gas and "waste, other biomass" in Energy Balance lines 11 and 15. Via cross-dependencies, the relevant time series of structural elements OEKW13, OEKW17, OEKWGUD, OEKWGM, HEKW13, HEKW17, HEKWGUD and HEKWGM (cf. Table 10) are thus also affected. Recalculation remains to be carried out for these time series.

- Plans call for breaking down raw-lignite inputs in public lignite-fired power stations – including inputs after 1994 – by mining district, in order to correct inconsistencies in the time series.
- The area of energy data for the new German Länder, for the years 1991-1994, is to be revised. This will compensate for inconsistencies in the time series.

As mentioned in previous chapters, a research project is currently underway that – inter alia – will review N_2O and CH_4 emission-factor time series for consistency between the period 1990 to 1994 and the period as of 1995 and that will propose changes, if necessary, in emission factors for the period 1990-1994. In addition, an effort will also be made to improve the database for methane emission factors.

Another emphasis of the project is to review the DFIU-determined emission factors for the year 2000, as well as the projected values for the year 2010. The aim of this work is to enhance methods for describing the chronological course of modernisations of existing plants and of adaptation of plants to tighter emissions standards. Work on the relevant follow-up research project began in summer 2004. This work has not yet been completed, and thus results will become available for use only as of 2006.

Longer-term plans call for enhancing precision in determination of N_2O/CH_4 emissions behaviour of gas turbines, via measurements and/or systematic studies. The occasions for these efforts include the circumstances described in Chapters 0 and 3.1.1.3.2, the increasing importance of gas turbines in the energy sector and in other industrial sectors, such as the refinery or the mining sectors, and Federal climate-protection efforts (especially gas and steam systems, CHP systems). The time for the start of this improvement measure has not yet been specified.

Calculations from the "limestone-balance" project will undergo specialised review by the 2007 report.

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

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

CRF 1.A.1.b					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
All Fuels	l / t	CO_2	1,54 %	1,85 %	rising

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	CS	CS	NO	NO	NO	CS	CS	CS	CS	CS
EF uncertainties in %	< 1	+/- 50	-	-	-	+/- 50				
Distribution of uncertainties	U	U	-	-	-	U				
Method of EF determination	CS	Tier 2	-	-	-	Tier 2				

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

In the area of CO_2 emissions from liquid fuels, the petroleum refining source category is a key category in terms of emissions levels and trend; in the area of CO_2 emissions from solid fuels, it is a key category in terms of trend.

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 Environmental Agency. The numbers themselves are based on a personal communication.

The crude oil distillation capacity of German petroleum refineries totalled around 116 Mt in the year 2004. Over this period, 112 Mt of crude oil, along with 11 Mt of intermediate products, were used for subsequent processing. Production of petroleum products totalled 120 Mt, 61 Mt of which consisted of fuels, 30 Mt of heating oils, 10 Mt of naphtha and 19 Mt of other products.

The refineries operate power stations with electrical output of about 0.9 GW. In 2004, these power stations generated 6 TWh of electrical work and provided process heat for production purposes.

Under source category 1.A.1.b, Petroleum refining, the CSE lists the sub-categories refinery process combustion, and heat and power production of refinery power stations.

Figure 18: Structural allocation 1.A.1b Petroleum refining

3.1.2.2 Methodological issues (1.A.1b)

The calculation method has been selected on the basis of the latest key-source analysis. For the *Balance of Emission Causes* (BEU), fuel use by refinery power stations was calculated from the Energy Balance figures (AGEB, 2003: line 12), and the fuel inputs for power stations for heat generation and for process combustion, which are listed jointly in line 38, were separated. Table 13 (refineries) shows the plant structure used in the BEU model.

The activity rates for 1990 for the new German Länder were revised and substantiated. The relevant methods and results are described in Annex 3 (Chapter 14.1.1).

The emission factors for refinery power stations have been taken from the research project Rentz et al. (2002). A detailed description of the procedure is presented in Chapter 3.1.1.2 and in Chapter 14.1.2.1 in Annex 3. The cited project does not provide any emission factors for the bottom-heating systems that provide process heat. To compensate for this gap, for bottom-heating systems the same values for N_2O and CH_4 were chosen that are also used for refinery power stations.

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

The procedure for determining uncertainties is described in Chapters 0 and 0.

The method for determining the uncertainties is described in Annex 2, Chapter 13.7.

3.1.2.3.1 Result for N_2O

The values for the relative uncertainty are on the order of about 0.6. The pertinent comments made in Chapter 3.1.1.3.2 also apply mutatis mutandis.

3.1.2.3.2 Result for CH_4

The results of uncertainties determination are described in Chapter 3.1.1.3.3.

3.1.2.3.3 Time-series consistency of emission factors

The results of determination of time-series consistency are described in Chapter 3.1.1.3.2.

3.1.2.4 Source-specific quality assurance / control and verification (1.A.1.b)

The 1990 fuel inputs for the new German Länder have been revised. A pertinent description is provided in the Annex, 14.1.1.

The results of the general procedure for source-specific quality assurance / control and verification are described in Chapter 3.1.1.3.2. In the past year, only a few, minor, quality assurance measures were carried out. These included correction of a number of individual values for the years 2001 and 2002 – previously, and erroneously, the value for 2000 had been adopted for those years; now, as in the procedure for all other time series, the values for these years have been obtained via linear interpolation between the values for 2000 and the projected values for 2010. (cf. Chapter 3.1.1.2).

3.1.2.5 Source-specific recalculations (1.A.1.b)

With regard to emissions data for N_2O and CH_4, recalculations have been completed for the current measures described in Chapter 3.1.2.4 (correction of emission factors).

3.1.2.6 Planned improvements (source-specific) (1.A.1b)

The planning described in Chapter 3.1.1.4 should also adequately improve the data situation for petroleum refineries. The already commenced research project described in the same chapter will also determine the emissions behaviour of refinery bottom-heating systems that provide process heat.

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

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

CRF 1.A.1c					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
All Fuels	l / t	CO_2	4,54 %	1,86 %	falling

Gas	CO_2	CH_4	HFC	PFC	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)	CS	CS	NO	NO	NO	CS	CS	CS	CS	CS
EF uncertainties in %	< 5	+/-50	-	-	-	+/- 50				
Distribution of uncertainties	U	U	-	-	-	U				
Method of EF determination	CS	Tier 2	-	-	-	Tier 2				

In light of its CO_2-emissions levels and trend, source category 1.A.1.c is a key category.

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

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 Environmental Agency. The numbers themselves are based on a personal communication.

This category includes hard-coal and lignite mining, coking and briquetting plants and extraction of crude oil and natural gas. In 2003, the German hard-coal mining sector extracted 25.9 Mt of usable hard coal. During the same period, coke production amounted to about 7.8 Mt (STATISTIK DER KOHLENWIRTSCHAFT, 2004)[13]. Together, production of hard-coal briquettes and other coal products totalled less than 1 Mt. An electrical power plant output of less than 3 GW, with a furnace thermal output of 7 GW, is attributable to hard-coal mining. Heat generation via combined heat and power generation is minimal.

In 2004, 181.9 Mt of crude lignite was produced in Germany. Production of lignite briquettes and other lignite products amounted to about 5 Mt (STATISTIK DER KOHLENWIRTSCHAFT, 2005). For production of such products in particular, the lignite-mining sector operates power stations with an electrical output of 0.5 GW and a furnace thermal output of 2 GW. From these plants, steam is drawn off for drying crude lignite for production of lignite products.

In 1998, German production of petroleum totalled just under 3 Mt, whilst production of natural gas totalled nearly 20,000 Mm³ (H_u = 31 736 kJ/m³). The fuel input needed for operation of the plants is included in the balance of emission causes (BEU).

In the CSE, source category 1.A.1.c Manufacture of solid fuels and other energy industries includes electricity and heat generation in steam-turbine power stations, broken down by hard-coal mining (STEAG, other pit power stations) and lignite mining (pit power stations), combined electricity and heat generation in gas turbines, gas engines and diesel engines of all pit (*Zeche* + *Grube*) power stations, other heat generation 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 pit (*Zeche* + *Grube*) power stations.

[13] p. 50, overview of figures 45, line for coke production

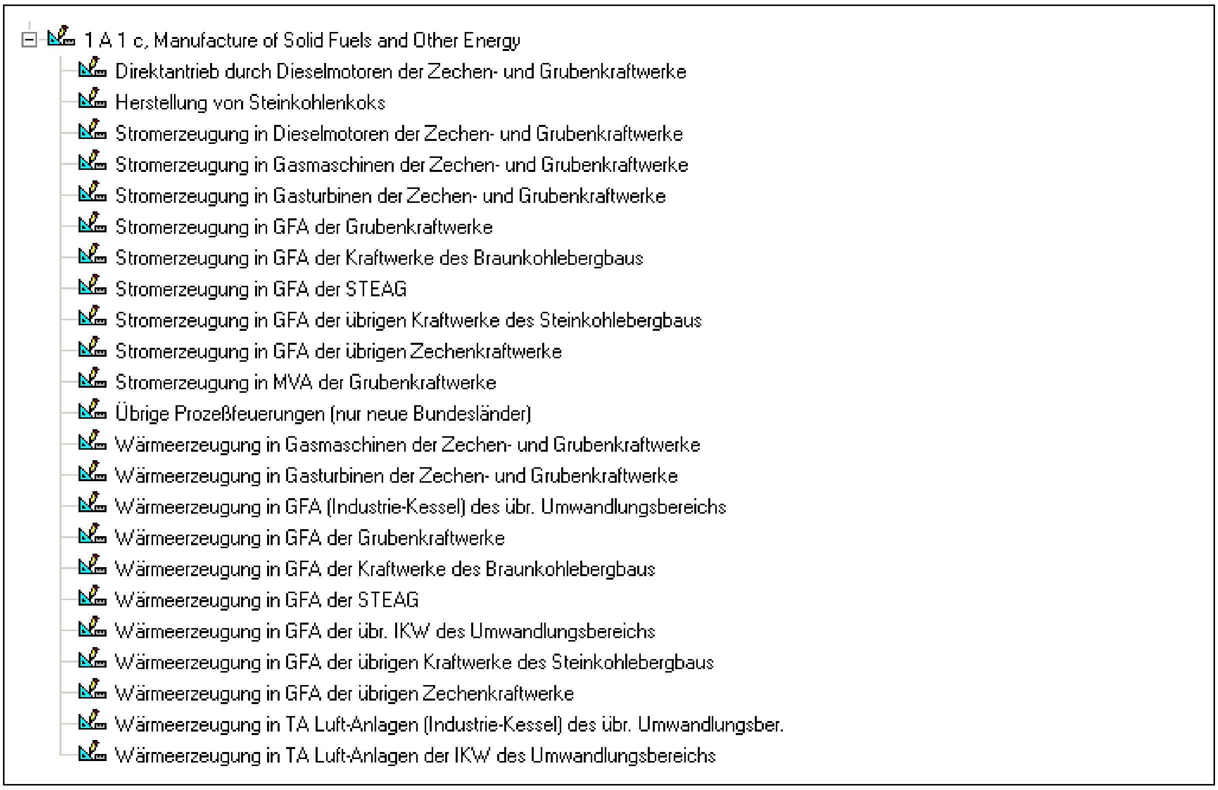


Figure 19: Structural allocation, 1.A.1c Manufacture of solid fuels and other energy industries

3.1.3.2 Methodological issues (1.A.1.c)

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

Table 11 shows the data structure, from the *Balance of Emission Causes*, for the hard-coal and lignite-mining sectors.

Table 13 shows the BEU structure for oil extraction.

The sources used for the production data include the Energy Balance for the Federal Republic of Germany (for the years 1990-1999 AGEB, 2003: 3.1, line 21), STATISTIK DER KOHLENWIRTSCHAFT (Statistics of the coal industry, 2004) and Statistik des produzierenden Gewerbes (Statistics of the manufacturing sector; DESTATIS, Fachserie 4 Reihe 3.1, 1991-2004: Produktion im Produzierenden Gewerbe; Melde-Nr. (reporting no.) 2310 10 330+350). The source for the fuel inputs is the Energy Balance for the Federal Republic of Germany (3.2 Joule), AGEB, 2003: line 33). Fichtner Beratende Ingenieure (FICHTNER, 1982) was also consulted.

The activity rates for 1990 for the new German Länder were revised and substantiated. The relevant methods and results are described in Annex 3 (Chapter 14.1.1).

The procedure described below is currently being used for preparation of activity-rate time series oriented to the territory of Germany as of 1995.

Data on energy consumption in hard-coal coking cannot be taken directly from the Energy Balance (AGEB, 2003: line 33, Own consumption of coking plants), since such consumption is only a sub-set of the data shown in the relevant Energy-Balance line. An approach using specific energy consumption was thus chosen for determining activity rates. From the aforementioned study (Fichtner, 1982), bottom heating of coking furnaces of mines' coking plants was found to have an average consumption of 2950 MJ coking-plant gas per tonne of coke. For metallurgical coking plants, this value is 5 % higher, or 3100 MJ per t coke, as a result of those plants' use of blast-furnace gas. Since no figures are available for local gas works, the specific consumption of mine coking plants is assumed for this category of bottom heating of coking furnaces.

The binding basic figure for determination of relevant energy inputs is the conversion output of coking plants pursuant to the Energy Balance (AGEB, 2003: line 21) in 1000 t of hard-coal coke. The Federal Statistical Office's relevant figures are used, as a recourse, only for those years for which no Energy Balance is available. The production of by-product coke is calculated from the difference between total hard-coal-coke production and metallurgical coke production, pursuant to the coal industry's statistics. The energy input, in TJ, for bottom heating of coking furnaces is obtained by multiplying the figures for mine and metallurgical coke production with the relevant specific energy consumptions. Consumption of blast-furnace gas pursuant to the Energy Balance (AGEB, 2003: line 33) has been allocated completely to bottom heating of coking furnaces, and the difference between this and total input is the figure for coke-furnace / city gas.

Table 19 shows the activity rates determined; lignite coking plants are not included, since no energy inputs are available for them.

Table 19: Determination of activity rates (AR) of emissions-relevant energy consumption (EMEV) of process combustion in hard-coal coking

Hard-coal coke production	**Unit**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Total 1)	[1000 t]	10662	10774	10325	8569	9141	7265	7226	7827
By-product (metallurgical) coke 2)	[1000 t]	5833	5859	5591	5195	5296	5274	5225	5790
Mine coke 3)	[1000 t]	4829	4915	4734	3374	3845	1991	2001	2037
Mean energy input									
Metallurgical coke	[TJ/kt]	3,1	3,1	3,1	3,1	3,1	3,1	3,1	3,1
Mine coke	[TJ/kt]	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95
Energy input for hard-coal coking									
Metallurgical coke	[TJ]	18082,3	18162,9	17332,1	16104,5	16417,6	16349,4	16197,5	17949
Mine coke	[TJ]	14245,5	14499,2	13965,3	9953,3	11342,8	5873,45	5902,95	6009,15
Total	[TJ]	32328	32662	31297	26058	27760	22223	22100	23958
EMEV hard-coal coking									
AR blast-furnace gas 4)	[TJ]	18172	19193	16861	12163	15662	16189	16397	14481
AR coke-furnace gas, city gas 5)	[TJ]	14156	13469	14436	13895	12098	6034	5703	9477

1) Energy Balance (AGEB 2003), line 21; 2000/2001/2002: DESTATIS Fachserie 4 Reihe 3.1, 1991-2004: Melde-Nr. 2310 10 330+350; 2002: Melde-Nr. 2310 10 300 as an additional aid; the figure for 2003 is from: Statistik der Kohlenwirtschaft e.V. (2004): Der Kohlenbergbau in der Energiewirtschaft der BRD im Jahre 2003, Zahlenübersicht 41 – with an estimate for the Duisburg-Schwelgern coking plant.
2) Statistik der Kohlenwirtschaft e.V. (2004): Der Kohlenbergbau in der Energiewirtschaft der Bundesrepublik Deutschland im Jahre 2003, Zahlenübersicht 45 – the figure for 2003 includes an estimate for the Duisburg-Schwelgern coking plant.
3) Total hard-coal-coke production except for by-product (metallurgical) coke
4) Total value from Energy Balance (AGEB 2003), line 33, for blast-furnace gas and converter gas; preliminary figures as of 2000.
5) Total energy input, except for AR for blast-furnace gas

The emission factors for power stations and other boiler combustion for production of steam and hot/warm water, in source category 1.A.1.c, have been taken from Rentz et al (2002). A detailed description of the procedure is presented in Chapter 3.1.1.2 and in Chapter 14.1.2.1 in Annex 3.

Within the sector, the research project differentiates 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.

Revision of the 1990 data for the new German Länder is described in Annex 14.1.1.

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

The procedure for determining uncertainties is described in Chapters 0 and 0.

The method for determining the uncertainties for the activity rates is described in the Annex, Chapter 13.7.

3.1.3.3.1 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, emissions behaviour in combustion of hard coal and lignite, especially in fluidised-bed combustion, has been specifically studied over the past 15 years. For this reason, enough measurement data was available to permit systematic survey of N_2O emission factors in the research project. The values for the relative uncertainty of the emission factors are on the order of about 0.6. The pertinent comments made in Chapter 3.1.1.3.2 also apply mutatis mutandis.

3.1.3.3.2 Result for CH_4

The results of uncertainties determination are described in Chapter 3.1.1.3.3.

3.1.3.3.3 Time-series consistency of emission factors

The results of determination of time-series consistency are described in Chapter 3.1.1.3.4.

3.1.3.4 Source-specific quality assurance / control and verification (1.A.1.c)

The results of the general procedure for source-specific quality assurance / control and verification are described in Chapter 3.1.1.3.2. In the past year, only a few, minor, quality assurance measures were carried out. These included filling-in of gaps in the area of small industrial boiler systems in the remaining transformation sector (all plants outside of the hard-coal/lignite mining sector). In addition, a number of individual values for the years 2001 and 2002 were corrected – previously, and erroneously, the value for 2000 had been adopted for those years; now, as in the procedure for all other time series, the values for these years have been obtained via linear interpolation between the values for 2000 and the projected values for 2010. (cf. Chapter 3.1.1.2)

3.1.3.5 Source-specific recalculations (1.A.1.c)

With regard to emissions data for N_2O and CH_4, recalculations have been completed for the current measures described in Chapter 3.1.2.4 (correction of emission factors and filling-in of gaps).

3.1.3.6 Planned improvements (source-specific) (1.A.1.c)

Modelling of energy inputs in the lignite-mining sector, as described in Chapter 13.8.1, has been introduced to the database for the year 2004. Relevant recalculation remains to be carried out.

The planning described in Chapter 3.1.1.6 will also adequately improve the data situation for emission factors for power stations and other combustion plants within the mining sector.

Review of existing emission factors in the area of coking plants, and of the consistency of pertinent time series, is planned for next year. In the interest of broadening the database, plans also call for development, with the help of relevant associations, operators and monitoring authorities, of a strategy for future data deliveries and uncertainties estimates. One lignite coking plant is still in operation in Germany. This coking plant's relevance for emissions reporting remains to be studied.

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

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

- 1 A 2, Manufacturing Industries and Construction
  - 1 A 2 a, Iron and steel
    - Herstellung von Eisen-, Stahl- und Temperguß (Prozeßfeuerung)
    - Herstellung von Roheisen (Prozeßfeuerung)
    - Herstellung von Siemens-Martin-Stahl (Prozeßfeuerung)
    - Herstellung von Sinter (Prozeßfeuerung)
    - Herstellung von Walzstahl (Prozeßfeuerung)
  - 1 A 2 b, Non-ferrous metals
    - Herstellung von Nichteisen-Schwermetalle (Prozeßfeuerung)
  - 1 A 2 c, Chemicals
    - Herstellung von Calciumcarbid (Prozeßfeuerung)
  - 1 A 2 d, Pulp, Paper and Print
    - Herstellung von Zellstoff u. Papier (Prozessfeuerung)
  - 1 A 2 e, Food Processing, Beverages and Tobacco
    - Herstellung von Zucker (Prozeßfeuerung)
  - 1 A 2 f, Other
    - 1 A 2 f, Cement production
      - Herstellung von Zementklinker (Prozessfeuerung)
    - 1 A 2 f, Ceramics
      - Herstellung von Grobkeramik (Prozeßfeuerung)
    - 1 A 2 f, Glass Production
      - Herstellung von Glas (Prozeßfeuerung)
    - 1 A 2 f, Lime production
      - Herstellung von Kalk (Prozeßfeuerung)
    - 1 A 2 f, Other manufacturing
      - Stromerzeugung in Dieselmotoren der übrigen Industriekraftwerke
      - Stromerzeugung in Gasmaschinen der übrigen Industriekraftwerke
      - Stromerzeugung in Gasturbinen der übrigen Industriekraftwerke
      - Stromerzeugung in GFA der DB-Kraftwerke
      - Stromerzeugung in GFA der übrigen Industriekraftwerke
      - Stromerzeugung in MVA der übrigen Industriekraftwerke
      - Stromerzeugung in TA Luft-Anlagen der übrigen Industriekraftwerke
      - Übrige Prozeßfeuerungen
      - Wärmeerzeugung in Dieselmotoren der IKW des verarb. Gewerbes und übr. Bergbaus
      - Wärmeerzeugung in Gasmaschinen der IKW des verarb. Gewerbes und übr. Bergbaus
      - Wärmeerzeugung in Gasturbinen der IKW des verarb. Gewerbes und übr. Bergbaus
      - Wärmeerzeugung in GFA (Industrie-Kessel) des verarb. Gewerbes und übr. Bergbaus
      - Wärmeerzeugung in GFA der IKW des verarb. Gewerbes und übr. Bergbaus
      - Wärmeerzeugung in GFA der Kraftwerke des Braunkohlebergbaus (für Industrie)
      - Wärmeerzeugung in GFA der öffentlichen Kraftwerke (für Industrie)
      - Wärmeerzeugung in KFA des verarb. Gewerbes u. übr. Bergb.
      - Wärmeerzeugung in KFA (Industriekessel) des übr. Bergbaus und verarb. Gewerbes (Heizungsanlagen)
      - Wärmeerzeugung in KFA (Industriekessel) des übr. Bergbaus und verarb. Gewerbes (Produktionswärme)
      - Wärmeerzeugung in MVA der IKW des verarb. Gewerbes und übr. Bergbaus
      - Wärmeerzeugung in TA Luft-Anl. (Ind.-Kessel) des verarb. Gewerbes u. übr. Bergb.
      - Wärmeerzeugung in TA Luft-Anl. (Industrie-Kessel) des übr. Bergb. u. verarb. Gew. (Heizungsanlagen)
      - Wärmeerzeugung in TA Luft-Anl. (Industrie-Kessel) des übr. Bergb. u. verarb. Gew. (Produktionswärme)
      - Wärmeerzeugung in TA Luft-Anl. der IKW des verarb. Gewerbes und übr. Bergbaus

Figure 20: Allocation of structural elements in source category 1.A.2 Manufacturing industries and construction

The following improvements over the last inventory have been made in source category 1.A.2:

An initial effort was made to break the source category down into sectors, in keeping with the IPCC's specifications.

For the first time, secondary fuels were also taken into account. These were identified via a current research project (UBA 2005b, FKZ 20442203/02).

The 1990 activity rates for the new German Länder have been revised (research project "Base year and updating" ("Basisjahr und Aktualisierung"), UBA, 2005c, FKZ 20541115).

The fossil and biogenic fractions of industrial waste are listed separately, in a 50/50 ratio (except in cases in which the industrial waste concerned clearly has a fossil fraction of 100%, as in the lignite mining sector, in which industrial waste consists of residual lignite substances).

Source category 1.A.2.f has been subdivided more finely than is required by the IPCC, since process-combustion models are available for certain sectors – in cases in which the pertinent fuel consumption in Germany is relevant (see Chapter 3.1.4.6). The figures for all sub-source categories, with the exception of those for 1.A.2.f Other, are solely for fuel use in process combustion and relevant emissions.

All of the listed amounts of standard fuels used in all sub- source 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- source categories secondary fuels have now been listed, for the first time. The relevant amounts have been determined in a current research project (UBA 2005b, FKZ 20442203/02) (see below). As these figures show, use of secondary fuels has been increasing. This has led to reductions in use of conventional fuels, via de facto fuel substitutions.

In the CSE, fuel-specific and sector-specific emission factors for the pertinent climate gases have been allocated to some of the structural elements listed in Figure 1, while analogous emission factors have been allocated to the remaining structural elments. Following emissions calculation at the structural-element level, sum values for the sub- source categories in 1.A.2 have been formed, via maximally IPCC-conformal aggregation of results, and then, in contrast to earlier reports, reported in disaggregated form. In a departure from the NIR 2005, in the NIR 2006 most process combustions have been reported on a sector-oriented basis. The available data does not permit fully IPCC-conformal aggregation. For example, heat and power production of industrial power stations and heat/power stations cannot be oriented to specific sectors; for this reason, it is reported in combined form, under 1.A.2.f Other.

Findings from one research project have further improved the data for source category 1.A.2. The research project "Inputs of secondary fuels" ("Einsatz von Sekundärbrennstoffen") (UBA 2005b, FKZ 20442203/02) was carried out on the basis of suggestions provided in the Climate Secretariat's independent review.

S&A II of the 2003 inventory states:
„...a better identification of the waste fuels that are used and provision of all such explanations may clarify these issues … fuel consumption for subcategory 1.A.2 Manufacturing Industries and Construction also require an explanation and further elaboration about fuel switching.“

In the research project "Inputs of secondary fuels" ("Einsatz von Sekundärbrennstoffen"), the required improvements relative to the topic of "waste fuels" in the energy sector were found to be tied to secondary fuels in four industrial sectors, and the pertinent data was obtained from the relevant industrial associations. As a result, the data for use of secondary fuels in process combustion in the industrial sectors pig-iron production, pulp and paper production and lime and cement production has been considerably improved. In some cases, the first sector-specific data for use of such fuels is now available.

For the year 2004, this inventory supplementation yielded some 5.3 million tonnes of CO_2 in addition to what was reported in earlier reports. In the revised structure of 1.A.2, this result corresponds to a share of about 5% of the total emissions of source category 1.A.2. Since about 2/3 of the pertinent emissions originate from use of biomass and/or biomass components, the relevant increased emissions of fossil CO_2 amount to only about 1.8 million tonnes, or about 1.5 %, in 1.A.2. Use of secondary fuels has nearly quadrupled since 1990, and it has continued to increase sharply since the year 2000 (with biomass use increasing disproportionately).

The data for secondary fuel use in process combustion has been implemented in the transmitted inventory, and it supplements the Balance of Emission Causes (BEU).

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

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

CRF 1.A.2.a					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
All Fuels	l / -	CO_2	0,64 %	0,60 %	fallend

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	CS	CS	NO	NO	NO	CS	CS	CS	CS	CS
EF uncertainties in %										
Distribution of uncertainties	N									
Method of EF determination	T2									

The source category Manufacturing industries and construction – iron and steel is a key category, in terms of emissions levels and trend, for CO_2 emissions from gaseous and solid fuels.

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

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

It comprises the production areas of pig iron (blast furnaces), sinter, rolled steel, iron and steel casting and Siemens-Martin steel.

Production of Siemens-Martin steel generated emissions only in the new German Länder, and only in the year 1990. Thereafter, production was completely discontinued. In the old German Länder, production of Siemens-Martin steel had been 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 use in other production areas of the iron and steel industry occurs in heat production.

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

This sub- source category covers process combustion in the various production areas of the iron and steel industry. The relevant fuel-use amounts, with the exception of those for secondary fuels, are contained in the *Balance of Emission Causes* (BEU). The fuel-use amounts were taken from manufacturing industry statistics for blast furnaces, sinter and rolled steel (Statistik des produzierenden Gewerbes (Hochofen, Sinter und Walzstahl: FS4, R 8.1 Tab. 3.25, Eisen-, Stahl- und Tempergießereien [iron and steel casting]: Melde-Nr. [reporting number] 27.21, 21.51 and 27.52).

This year's report introduces a new distinction in the area of emissions from the iron and steel industry, for the entire time series as of 1990: between process-related emissions (reported under 2.C.1, Chapter 4.3.1) and energy-related emissions. The pertinent share for process-related emissions is calculated with the same method that is used for emissions trading. This method is described in detail in Annex Chapter 14.2.3.1.

As of 1995, the values in the column "Other petroleum products" of line 54 (metal production) of the Energy Balance are allocated to the blast-furnace process as activity rates. The following changes were implemented for sinter production, for the entire time series:

a) The values in the columns "Lignite briquettes" and "Lignite coke" of line 54 of the Energy Balance have been allocated to sinter production.

b) On the basis of the specific gas consumption per tonne of "finished sinter", equal shares of natural gas, blast-furnace gas and coke-oven / city gas were assigned to sinter production.

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

Uncertainties were determined for all fuels in 2004, and for substitute reducing agents, with regard to the entire time series. The relevant method is explained in Annex 2 and in the research report (UBA 2005b, FKZ 20442203/02).

Revision of the activity data for 1990 has produced some inconsistencies for the 1990-1994 period.

3.1.4.1.4 Source-specific quality assurance / control and verification (1.A.2.a)

In a research project (UBA 2005b, FKZ 20442203/02), the time-series data provided by the Wirtschaftsvereinigung Stahl steel-industry association for use of substitute reducing agents in the steel industry was subjected to intensive quality checks. In the process, the steel industry's total reducing-agent and fuel inputs from standard fossil fuels were determined and then compared with consumption of substitute reducing agents. In addition, the determined CO_2 emissions from regular and substitute reducing agents were assessed.

In a project (UBA, 2005c, FKZ 20541115), the 1990 activity rates for the new German Länder were revised and then improved with regard to specific sectors; see Annex Chapter 14.1.1.

3.1.4.1.5 Source-specific recalculations (1.A.2.a)

The changes in the database for the new German Länder, for 1990, as well as those in calculation procedures (cf. Chapter 3.1.4.1.2),led to recalculations on the structural element level. A slight increase in activity rates resulted for the entire sub- source category 1.A.2.a.

It should be noted that the relevant calculation procedure was modified.

3.1.4.1.6 Planned improvements (source-specific) (1.A.2.a)

No improvements are planned at present.

3.1.4.2 Manufacturing industries and construction – Non-ferrous metals (1.A.2.b)

CRF 1.A.2.b					
Key category by level (l) / trend (t)		Gas (key category)	1990 - contribution to total emissions	2004 - contribution to total emissions	Trend
	- / -				

Gas	CO_2	CH_4	HFC	PFC	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)	CS	CS	NO	NO	NO	CS	CS	CS	CS	CS
EF uncertainties in %										
Distribution of uncertainties										
Method of EF determination										

This source category is not a key category.

3.1.4.2.1 Source-category description (1.A.2.b)

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

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

The pertinent fuel inputs are contained in the Balance of Emission Causes (BEU). The fuel-input data was taken from manufacturing industry statistics (Melde-Nr. (reporting number) 27.43, Erzeugung und erste Bearbeitung von Blei, Zink und Zinn (Production and initial processing of lead, zinc and tin) and 27.44, Erzeugung und erste Bearbeitung von Kupfer (Production and initial processing of copper)).

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.

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

The uncertainties for all fuels were determined for 2004. The relevant method is described in Annex Chapter 13.7.

In the project "Base year and updating" ("Basisjahr und Aktualisierung" (UBA 2005c: FKZ 20541115), the activity rates for the new German Länder for 1990 were revised, on the basis of new data, and described; see Annex Chapter 14.1.1). As a result, some inconsistencies have occurred for the period 1990-1994.

3.1.4.2.4 Source-specific quality assurance / control and verification (1.A.2.b)

In the research project "Base year and updating" (UBA 2005c, FKZ 20541115), the 1990 activity rates for the new German Länder were revised and improved using production indexes.

3.1.4.2.5 Source-specific recalculations (1.A.2.b)

In this sub- source category, improvements in the basic data for the new German Länder for 1990 led to increases in activity rates and CO_2 emissions.

3.1.4.2.6 Planned improvements (source-specific) (1.A.2.b)

Review is currently underway to determine to what extent the database changes brought about by the Energy Statistics Act (Energiestatistikgesetz; 1 January 2003) will make it possible also to report emissions from the manufacturing sector's power stations on a sector-specific basis.

Plans call for improving the consistency of the time series, which has worsened in some cases.

3.1.4.3 Manufacturing industries and construction – Chemicals (1.A.2.c)

CRF 1.A.2.c					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
All Fuels	IE	IE	IE	IE	IE

The chemical industry's process combustion and own power generation are not listed separately; instead, they are summarised in 1.A.2.f Other.

Fuel inputs in calcium-carbide production are process-related and are reported under CRF 2.B.4 (cf. Chapter 4.2.4).

This approach has been confirmed by the research project "Base year and updating" (UBA 2005c, FKZ 20541115), 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- source category 1.A.2.c are thus included elsewhere (IE). 1.A.2.c is not listed separately in the key-source analysis. Disaggregation of sub- source category 1.A.2.f Other may make it possible to consider this sub- source category separately in future.

3.1.4.4 Manufacturing industries and construction – Pulp, paper and print (1.A.2.d)

CRF 1.A.2.d					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
	- / -				

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	CS	NE	NO	NO	NO	NE	NE	NE	NE	NE
EF uncertainties in %	-50 / +90									
Distribution of uncertainties	N									
Method of EF determination	T2									

This source category is not a key category.

3.1.4.4.1 Source-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 secondary 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 generation, have not been listed separately. They are summarised under 1.A.2.f Other.

3.1.4.4.2 Methodological issues (1.A.2.d)

The procedure described here almost completely replaces the procedure, as described in Annex 2 of the NIR 2005, for determining inputs of spent sulphite liquor for heat and power generation. Because the available data sources do not permit continued use of the original procedure, only one time series – 1990 to 1994 – remains, with Energy Balance data.

The secondary fuels considered in the findings of the research project "Inputs of secondary fuels" ("Einsatz von Sekundärbrennstoffen" (UBA 2005b, FKZ 20442203/02) are either not included or only partly included 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 was provided by the German Pulp and Paper Association (VDP). The great majority of the secondary fuels used in the sector consist of wood and pulp fibres – and, thus, of biomass. As part of the research project, the fuels' biogenic and fossil fractions were determined. In addition, CO_2 emission factors were derived on the basis of data on carbon content, water content and net calorific values. Such data cannot be broken down by power and heat generation. For this reason, it is currently assigned completely to process combustion.

Table 20: Inputs of secondary fuels in the pulp and paper industry: CO_2 emission factors and their biogenic components

Secondary fuel (Designation in the CSE)	**CO_2 emission factor [kg/ TJ]**	**Biogenic mass fraction [%]**
Spent liquors from pulp production	74.046	100
Bark	80.611	100
Fibre/de-inking residues	54.871	100
Paper-industry residues	86.222	95

3.1.4.4.3 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 secondary fuels were determined using the Monte Carlo method (UBA 2005b, FKZ 20442203/02). In the procedure, figures for C content, water content and net calorific value were taken into account. Such figures are based on fluctuating estimates, as well as on small numbers of measurements and analysis findings, and thus are widely distributed. 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.

3.1.4.4.4 Source-specific quality assurance / control and verification (1.A.2.d)

The data on inputs of secondary fuels in the paper industry were provided by the German Pulp and Paper Association (VDP) and subjected to intensive quality checks in the framework of a research project (UBA 2005b, FKZ 20442203/02). In the process, the relevant physical amount flows were checked for consistency with overall energy consumption in paper production. In addition, CO_2 emissions from use of regular and substitute fuels were determined, as a means of checking the quality of the underlying data.

A total of 19.3 million t of paper, cardboard and carton were produced in Germany in 2003. In the process, a total of 260 PJ of thermal and electrical energy were consumed, of which over 25 PJ were obtained from renewable secondary fuels. As a result, the industry uses secondary fuels to meet some 20 % of its total thermal requirements. From this energy consumption, a total of 6.6 million t of CO_2 emissions were calculated for 2003 (not including renewable secondary fuels). Currently, some 2 million t of CO_2 from use of secondary fuels must be added to this. In the paper industry, some 99 % of these CO_2 emissions are generated through use of biogenic secondary fuels.

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 secondary fuels as substitutes for regular fuels.

3.1.4.4.5 Source-specific recalculations (1.A.2.d)

The total determined inputs of secondary fuels, and the emissions calculated on the basis of such inputs, add to the existing inventory.

3.1.4.4.6 Planned improvements (source-specific) (1.A.2.d)

Plans call for carrying out further checks aimed at ruling out proportional double-counting in the context of the Energy Balance. In future, it may become possible to differentiate the relevant fuel inputs by heat and power generation.

3.1.4.5 Manufacturing industries and construction – Sugar production (1.A.2.e)

CRF 1.A.2.e					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
	- / -				

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	CS	CS	NO	NO	NO	CS	CS	CS	CS	CS
EF uncertainties in %										
Distribution of uncertainties										
Method of EF determination										

This source category is not a key category.

3.1.4.5.1 Source-category description (1.A.2.e)

This source category includes only the sugar industry's process combustion using conventional fuels. Plants generating their own power are not listed separately; these are reported under 1.A.2.f Other.

3.1.4.5.2 Methodological issues (1.A.2.e)

The pertinent fuel inputs are contained in the Balance of Emission Causes (BEU). The fuel input data has been taken from manufacturing industry statistics (Statistik des produzierenden Gewerbes; Melde-Nr. (reporting no.) 15.83, sugar production).

Because large amounts of this industry's energy generation consist of combined heat/power (CHP) generation, only part of the spectrum of pertinent fuels was considered relevant to process combustion. This decision was applied throughout the entire time series. The fuel inputs for the new German Länder in 1990 were recalculated on the basis of specific fuel consumption in 1989 and production in 1990.

3.1.4.5.3 Uncertainties and time-series consistency (1.A.2.e)

The uncertainties for all fuels were determined for 2004. The relevant method is described in Annex Chapter 13.7.

Revision of the activity data for 1990 has produced some inconsistencies for the 1990-1994 period. These time series will be reworked in the course of the coming year.

3.1.4.5.4 Source-specific quality assurance / control and verification (1.A.2.e)

The results of the research project "Base year and updating" ("Basisjahr und Aktualisierung"; UBA 2005c, FKZ 20541115), which draw on production indexes, represent an improvement in the 1990 activity rates for the new German Länder.

3.1.4.5.5 Source-specific recalculations (1.A.2.e)

Small amounts of recalculations were carried out in this sub- source category, as a result of improvements in the available data for 1990.

3.1.4.5.6 Planned improvements (source-specific) (1.A.2.e)

No improvements are planned at present.

3.1.4.6 Manufacturing industries and construction – Other (1.A.2.f, sum)

CRF 1.A.2.f					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
All fuels	l / t	CO_2	11,36	9,00	falling

The source category Other (1.A.2.f), the sum of all other sub- source categories, is a key category, in terms of emissions levels and trend, for CO_2 emissions from gaseous, solid and liquid fuels. Key-source analysis was carried out only for the sum of sub- source categories in 1.A.2.f.

As a result of the pertinent inventory structure, the NIR includes the sub- source categories 1.A.2.f Cement (structural element "Production of cement clinkers (process combustion)"), 1.A.2.f Ceramics (structural element "Production of coarse ceramics (process combustion)"), 1.A.2.f Glass (structural element "Production of glass (process combustion)"), 1.A.2.f Lime (structural element "Production of lime (process combustion)") and 1.A.2.f Other ("other manufacturing" in the CSE, with various structural elements) (cf. Figure 1).

Binding key-source analysis has been carried out. In addition, the emissions-dominant sub-source categories can be listed. 1.A2.f Cement and 1.A.2.f Other are worthy of special note: 1.A2.f Cement as a significant source of process combustion, and 1.A.2.f Other as a collective group that includes emissions from heat and power generation of industrial power stations, as well as (inter alia) energy-related emissions from the chemical industry.

3.1.4.7 Manufacturing industries and construction – Cement production (1.A.2.f, Cement)

Gas	CO_2	CH_4	HFC	PFC	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)	CS	NE	NO	NO	NO	NE	NE	NE	NE	NE
EF uncertainties in %	-30 / +30									
Distribution of uncertainties	N									
Method of EF determination	T2									

Outside of the binding key-source analysis, this sub- source category must be considered particularly significant; it contributes nearly one percent to the total inventory.

3.1.4.7.1 Source-category description (1.A.2.f, Cement)

In this source category, only process combustion from burning of clinkers can be 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). Some plants within this category also generate power for their own use; this generation is not listed separately, but is included under 1.A.2.f Other.

In addition to substitutions of raw materials (smelter slag instead of cement clinkers, a subject not treated here in its own right), cement production involves considerable fuel substitutions in burning of clinkers. In the process, both conventional fuels, such as lignite, hard coal, oil and gas, and "secondary fuels" (waste from other economic sectors) are used. This reduces consumption of regular fuels.

3.1.4.7.2 Methodological issues (1.A.2.f, Cement)

The pertinent inputs of conventional fuels are contained in the Balance of Emission Causes (BEU). The fuel input data has been taken from manufacturing industry statistics (Statistik des produzierenden Gewerbes; Melde-Nr. (reporting no.) 26.51, cement production). For purposes of the BEU, the fuel inputs listed in that source are combined with the fuels petroleum coke and other petroleum products listed in line 53 (processing of non-metallic minerals) of the Energy Balance, since the fuel inputs go completely to rotating-drum ovens for cement. 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 uses significant amounts of secondary fuels that do not appear in national statistics and in the Energy Balance. Relevant production figures and fuel-use amounts have been taken from statistics of the VDZ cement-industry association. 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 20442203/02). Data on the relevant types, amounts and energy contributions of the secondary fuels used was provided by the VDZ.

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 secondary fuels, on the basis of data on carbon content, water content and net calorific value (UBA 2005b, FKZ 20442203/02).

Table 21: Inputs of secondary fuels in the cement industry: emission factors and their biogenic components

Secondary fuel (Designation in the CSE)	CO_2 emission factor [kg/ TJ]	Biogenic mass fraction [%]
Recycled tyres	97.319	27
Recycled oil	78.689	0
Commercial waste - paper	64.881	91
Commercial waste - plastic	83.075	0
Commercial waste - packaging	56.854	40
Textile waste	63.294	70
Commercial waste - other	68.129	52,33
Animal meals and fats	74.867	100
Processed municipal waste	59.846	55
Waste wood (wood scraps)	95.056	100
Solvents (waste)	71.133	0
Carpet waste	80.425	36,50
Bleaching clay	82.260	0
Sewage sludge	95.110	100
Oil sludge	84.024	0

3.1.4.7.3 Uncertainties and time-series consistency (1.A.2.f, Zement)

In the framework of the research project "Inputs of secondary fuels", the uncertainties of the CO_2 emission factors derived for secondary fuels were determined using the Monte Carlo method (UBA 2005b, FKZ 20442203/02). In the procedure, figures for C content, water content and net calorific value were taken into account. Such figures are based on fluctuating estimates, as well as on small numbers of measurements and analysis findings, and thus are widely distributed. 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.

Uncertainties were determined for all fuels in 2004 and for the aforementioned secondary fuels with regard to the entire time series. The relevant method is explained in Annex 13.7 and in the final report of the research project (UBA 2005b, FKZ 20442203/02).

Revision of the activity rates for 1990 has produced some inconsistencies for the 1990-1994 period.

3.1.4.7.4 Source-specific quality assurance / control and verification (1.A.2.f, Cement)

In the "Base year" research project ("Basisjahr"; UBA 2005c, FKZ 20541115), the existing 1990 data for the new German Länder was checked, using production indexes, and improved.

In the research project "Inputs of secondary fuels", the newly produced data series for inputs of secondary fuels in the cement industry were subjected to intensive quality checks (UBA 2005b, FKZ 20442203/02). In addition, figures of the Verein der Zementindustrie (VDZ) cement-industry association were checked for validity and integrated within their proper sectoral context.

On the basis of the newly obtained data, the following empirical picture results for the cement industry: Under current technological standards, production of one tonne of cement requires 2,982 MJ of fuels and 102 kWh of electrical power. With production of 32 million t, this relationship results in a total energy consumption of 107.1 PJ (including secondary fuels) for

2004 . In 2004, secondary fuels accounted for over 42 % of total thermal fuel consumption (95.3 PJ). The corresponding figure for 2001 was only 30 %.

Total thermal consumption of regular fuels generated 5.2 million t of CO_2 emissions in 2004. According to initial preliminary calculations for 2004, inputs of secondary fuels in the cement industry generated 3.1 million t of CO_2 emissions. This emissions volume includes about 1 million t of CO_2 emissions from biogenic fractions of the secondary fuels used. Rough calculations show that inputs of secondary fuels contribute significantly to CO_2-emissions reduction – even though they are not considered CO_2-neutral in the present context. The reason is that in the cement industry secondary fuels primarily replace solid fuels with a CO_2 emission factor of 93 kg/GJ. For comparison: the average emission factor of all secondary fuels (including biogenic fractions) used in 2004 in cement production was 77 kg/GJ.

3.1.4.7.5 Source-specific recalculations (1.A.2.f Cement)

Source-specific recalculations result in that the database has been expanded via inclusion of activity rates of secondary fuels. For the cement industry, fuel substitution is now included as a process that has continued over the past few years. In comparison to past reports, this results in an increase in listed emissions, although in some cases it results only in increases in biomass inputs.

Due to improvements in data on inputs of conventional fuels in 1990, only minor recalculations were carried out.

3.1.4.7.6 Planned improvements (source-specific) (1.A.2.f, Cement)

Review is currently underway to determine to what extent the database changes brought about by the Energy Statistics Act (Energiestatistikgesetz; 1 January 2003) will make it possible also to report emissions from the manufacturing sector's power stations on a sector-specific basis.

3.1.4.8 Manufacturing industries and construction – Ceramics (1.A.2.f, Ceramics)

Gas	CO_2	CH_4	HFC	PFC	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)	CS	CS	NO	NO	NO	CS	CS	CS	CS	CS
EF uncertainties in %										
Distribution of uncertainties										
Method of EF determination	CS					CS				

This sub- source category, with somewhat over a million tonnes of carbon dioxide, is not particularly significant.

3.1.4.8.1 Source-category description (1.A.2.f, Ceramics)

Source category Ceramics, 1.A.2.f, includes process combustion in the brick industry, including other construction ceramics. Some plants within this category also generate power for their own use; this generation is not listed separately, but is included under 1.A.2.f Other.

3.1.4.8.2 Methodological issues (1.A.2.f, Ceramics)

The pertinent fuel inputs are contained in the Balance of Emission Causes (BEU). The fuel input data has been taken from manufacturing industry statistics (Statistik des produzierenden Gewerbes; Melde-Nr. (reporting no.) 26.40, Ziegelei (brickworks), production of other construction ceramics).

3.1.4.8.3 Uncertainties and time-series consistency (1.A.2.f, Ceramics)

Uncertainties were determined for all fuels for the year 2004. The relevant method is described in Annex Chapter 13.7.

The uncertainties for emission factors and time-series consistency have not yet been studied for this sub- source category.

3.1.4.8.4 Source-specific quality assurance / control and verification (1.A.2.f, Ceramics)

In the "Base year" research project ("Basisjahr"; UBA 2005c, FKZ 20541115), the existing 1990 data for the new German Länder was checked, using production indexes, and improved.

3.1.4.8.5 Source-specific recalculations (1.A.2.f, Ceramics)

Small amounts of recalculations were carried out in this sub- source category, as a result of improvements in the available data for 1990.

3.1.4.8.6 Planned improvements (source-specific) (1.A.2.f, Ceramics)

Review is currently underway to determine to what extent the database changes brought about by the Energy Statistics Act (Energiestatistikgesetz; 1 January 2003) will make it possible also to report emissions from the manufacturing sector's power stations on a sector-specific basis.

The relevant uncertainties and time-series consistency are to be reviewed.

3.1.4.9 Manufacturing industries and construction – Glass (1.A.2.f, Glass production)

Gas	CO_2	CH_4	HFC	PFC	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)	CS	CS	NO	NO	NO	CS	CS	CS	CS	CS
EF uncertainties in %										
Distribution of uncertainties										
Method of EF determination	CS					CS				

This sub- source category, with some three million tonnes of carbon dioxide, must be considered significant.

3.1.4.9.1 Source-category description (1.A.2.f, Glass)

This sub- source category includes process combustion for the areas of flat-glass production, concave-glass production and production and treatment of other glass and technical glass products.

Some plants within this category also generate power for their own use; this generation is not listed separately, but is included under 1.A.2.f Other.

3.1.4.9.2 Methodological issues (1.A.2.f, Glass)

The pertinent fuel inputs are contained in the Balance of Emission Causes (BEU). The fuel input data has been taken from manufacturing industry statistics (Statistik des produzierenden Gewerbes; Melde-Nr. (reporting no.) 26.11, 26.13 and 26.15).

3.1.4.9.3 Uncertainties and time-series consistency (1.A.2.f, Glass)

Since 1995, when official statistics were converted to the economic-sector classification system (Klassifikation der Wirtschaftszweige; DESTATIS, 2002c), only one set of statistics has been used for Germany as a whole. This has considerably improved time-series consistency in comparison to that for the period 1990 to 1994.

Uncertainties were determined for all activity rates for the year 2004. The relevant method is described in Annex Chapter 13.7.

3.1.4.9.4 Source-specific quality assurance / control and verification (1.A.2.f, Glass)

In the research project "Base year and updating" (UBA 2005c, FKZ 20541115), the available data for 1990 for the new German Länder was revised and improved using production indexes.

3.1.4.9.5 Source-specific recalculations (1.A.2.f, Glass)

Minor recalculations were carried out in this sub- source category as a result of improvements in data for 1990; this led to reductions in the relevant activity rates.

3.1.4.9.6 Planned improvements (source-specific) (1.A.2.f, Glass)

Review is currently underway to determine to what extent the database changes brought about by the Energy Statistics Act (Energiestatistikgesetz; 1 January 2003) will make it possible also to report emissions from the manufacturing sector's power stations on a sector-specific basis.

3.1.4.10 Manufacturing industries and construction – Lime (1.A.2.f, Lime production)

Gas	CO_2	CH_4	HFC	PFC	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)	CS	CS	NO	NO	NO	CS	CS	CS	CS	CS
EF uncertainties in %										
Distribution of uncertainties										
Method of EF determination	CS									

This sub- source category, with somewhat over a million tonnes of carbon dioxide, is not particularly significant.

3.1.4.10.1 Source-category description (1.A.2.f, Lime)

With regard to conventional fuels, the process combustion figures refer to production of lime and mortar.

The reported figures for inputs of secondary fuels refer to all process combustion in German lime works.

3.1.4.10.2 Methodological issues (1.A.2.f, Lime)

The calculation method has been selected on the basis of the latest key-source analysis. The relevant inputs of regular fuels are contained in the Balance of Emission Causes (BEU). The fuel input data has been taken from manufacturing industry statistics (Statistik des produzierenden Gewerbes; Melde-Nr. (reporting no.) 26.52/Lime, 26.64/Mortar). 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.

Since 2003, the lime industry has used minor amounts of secondary fuels that do not appear in national statistics and in the Energy Balance. The fuel-input data was provided by the Bundesverband der Deutschen Kalkindustrie national lime-industry association. The procedure used to compile activity data oriented to the territory of Germany, for the period as of 2003, is described in the final report of the research project "Use of secondary fuels" ("Einsatz von Sekundärbrennstoffen"; UBA 2005b, FKZ 20442203/02). The data on the types and amounts of secondary fuels used was provided by the Bundesverband der Deutschen Kalkindustrie national lime-industry association. 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 secondary fuels, on the basis of data on carbon content, water content and net calorific value (UBA 2005b, FKZ 20442203/02).

Table 22: Inputs of secondary fuels in the lime industry: emission factors and their biogenic components

Secondary fuel (Designation in the CSE)	CO_2 emission factor [kg/ TJ]	Biogenic mass fraction [%]
Recycled oil	78.689	0
Animal meals and fats	74.867	100
Commercial waste - other	68.129	52,33

3.1.4.10.3 Uncertainties and time-series consistency (1.A.2.f, Lime)

Since 1995, when official statistics were converted to the economic-sector classification system (Klassifikation der Wirtschaftszweige; DESTATIS, 2002c), only one set of conventional-fuel statistics has been used for Germany as a whole. This has considerably improved time-series consistency in comparison to that for the period 1990 to 1994.

Uncertainties were determined for all regular fuels for the year 2004. The relevant method is described in Annex Chapter 13.7.

In the framework of the research project "Inputs of secondary fuels" (UBA 2005b, FKZ 20442203/02), the uncertainties of the CO_2 emission factors derived for secondary fuels were determined using the Monte Carlo method . Such figures are based on fluctuating estimates, as well as on small numbers of measurements and analysis findings, and thus are widely distributed. 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.

3.1.4.10.4 Source-specific quality assurance / control and verification (1.A.2.f, Lime)

In the research project "Inputs of secondary fuels" (UBA 2005b, FKZ 20442203/02), the time series for data on secondary-fuel inputs in the lime industry were also intensively checked for consistency and plausibility. To this end, the industry's entire energy and emissions situation was considered – as has been the procedure for other economic sectors with secondary-fuel inputs. On the other hand, such quality assurance is subject to the constraint that the relevant data provided by the Bundesverband Kalk lime-industry association begins with the year 2003. As a result, only one observation time is available; i.e., no time series are available.

A total of 6.5 million t of lime was produced in 2003. This required fuel inputs with an energy equivalent of 27.7 PJ. In addition, in 2003 the lime industry consumed some 2.4 PJ of secondary fuels, meaning that such fuels met about 8 % of the industry's total fuel requirements. Regular-fuel inputs for lime production generated a total of 2.3 million t of CO_2 emissions. Inputs of secondary fuels in the lime industry in 2003 generated a total of 180,000 t of CO_2 emissions. The data obtained fit with the overall picture for the sector, in light of relevant other fuel consumption and the pertinent CO_2 emissions.

3.1.4.10.5 Source-specific recalculations (1.A.2.f, Lime)

Minor source-specific recalculations were carried out, because the database was expanded via inclusion of activity rates of secondary fuels.

Minor recalculations were carried out due to improvements in the data on regular fuel inputs for 1990.

3.1.4.10.6 Planned improvements (source-specific) (1.A.2.f, Lime)

No further improvements are planned at present.

3.1.4.11 Manufacturing industries and construction – Other energy production (1.A.2.f, Other)

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	CS	CS	NO	NO	NO	CS	CS	CS	CS	CS
EF uncertainties in %	NE	NE				NE				
Distribution of uncertainties										
Method of EF determination	CS	CS				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- source category is particularly significant; it contributes about 10 % of the entire energy sector's CO_2 emissions.

3.1.4.11.1 Source-category description (1.A.2.f Other)

In this sub- source 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- source category is responsible for about ¾ of all CO_2 emissions of source category 1.A.2. When emissions from use of biomass in process combustion are not included, its share becomes even larger.

All heat and power generation in industrial power stations is listed in this sub- source category. All energy-related emissions from the chemical industry are also reported in it. No specific data is assigned to the structural element "Other process combustion". A large part of the energy inputs listed in 1.A.2.f Other should really be allocated to the various corresponding sectors. The available data does not permit such allocation, however. All other descriptions for this highly heterogeneous area of the emissions inventory should be seen as orientational in nature and as the beginning of an improvement procedure.

3.1.4.11.2 Methodological issues (1.A.2.f Other)

In the BEU, the Energy Balance energy inputs continue to be broken down by heat generation and power generation; the relevant procedure is described in Annex 2.

The emission factors for power stations and other boiler combustion for production of steam and hot/warm water, in source category 1.A.2f / all other, have been taken from Rentz et al (2002). A detailed description of the procedure is presented in Chapter 3.1.1.2 and in Chapter 14.1.2.1 in Annex 3. The research project breaks 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.

3.1.4.11.3 Uncertainties and time-series consistency (1.A.2.f Other)

Activity rates:

The uncertainties were determined for 2004. The relevant method is described in Annex 2.

Emission factors:

The procedure for determining uncertainties is described in Chapters 3.1.1.2.

Result for N_2O: The results are described in Chapter 3.1.1.3.2.

Result for CH_4: The results of uncertainties determination are described in Chapter 3.1.1.3.3.

The results of determination of time-series consistency are described in Chapter 3.1.1.3.4.

3.1.4.11.4 Source-specific quality assurance / control and verification (1.A.2.f Other)

Activity rates:

It has not yet been possible to carry out general quality control (Tier 1) in conformance with the requirements of the QSE manual and its associated applicable documents. For this reporting year, an emphasis was placed on disaggregating the sub- source categories in 1.A.2. It has not yet been possible to make any improvements in the remaining group that has not yet been disaggregated.

Emission factors:

The results of the general procedure for source-specific quality assurance / control and verification are described in Chapter 3.1.1.4. In the past year, only a few, smaller quality assurance measures were carried out; these include closures of gaps in the area of small industrial boiler combustion and in use of other petroleum products (including refinery residues, bitumen, recycled oil and special and test benzines, paraffins and waxes, where such substances are used for energy recovery); in addition, individual values for 2001 and 2002 were corrected; previously, the value for the year 2000 was simply (and erroneously) also used for those years; now, as is the procedure for all other time series, the values for these years are determined via linear interpolation between the values for 2000 and the projected values for 2010. (cf. Chapter 3.1.1.2).

3.1.4.11.5 Source-specific recalculations (1.A.2.f Other)

Activity rates:

Source-specific recalculations resulted in that source-category differentiation was carried out for the first time. Minor recalculations were carried out due to improvements in the data on conventional fuels for 1990.

For the 2004 reporting year, some improvements in the calculation algorithms in Energy Balance line 60 (heat production in connection with extraction of non-metallic minerals, other mining, processing sector overall) were entered into the database. The improvements were achieved primarily in modelling of fuel inputs in process combustion. In addition, errors in disaggregation of combustion inputs of hard coal and "Waste, other biomass" in Energy Balance line 60 were eliminated.

Emission factors:

No recalculations have been carried out in connection with the emission factors for N_2O and CH_4, since the current quality assurance measures (described in Chapter 3.1.4.11.4) have not had any significant impacts on source-specific emissions.

3.1.4.11.6 Planned improvements (source-specific) (1.A.2.f Other)

Activity rates:

As a result of the cross-dependencies in modelling of disaggregation of combustion inputs of hard coal and "Waste, other biomass" in Energy Balance line 60, all of the time series allocated to Energy Balance line 60 have to be recalculated.

Emission factors:

The planning described in Chapter 3.1.4.11.4 should also adequately improve the data for power stations, gas turbines and industrial boiler combustion.

3.1.5 Transport (1.A.3)

3.1.5.1 Transport - Civil aviation (1.A.3.a)

3.1.5.1.1 Source-category description (1.A.3.a)

CRF 1.A.3					
Key category		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
Aviation Gasoline	- / t	CO_2	0,23 %	0,42 %	rising

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	CS	CS	--	--	--	CS	CS	CS	CS	CS
EF uncertainties in %										
Distribution of uncertainties										
Method of EF determination	T1	T1	--	--	--	T1				

In terms of emissions levels and trend, civil air transport is a keycategory.

In terms of emissions origins, air transports differ considerably from land and water transports, since aircraft burn most of their fuel under atmospheric conditions that differ from those on the ground and that are not constant. The main factors that influence the combustion process in this sector include atmospheric pressure, environmental temperature and humidity – all of which are factors that vary considerably with altitude.

In addition to considering carbon dioxide, the debate on the climate effects and emissions-related environmental impacts of air transports focuses mainly on water vapour and nitrogen oxides and, secondarily, on hydrocarbons, particulates, CO 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 sulphur dioxide (SO_2), nitrogen oxides (NO_X, i.e. NO and NO_2), non-methane volatile organic compounds (NMVOC), methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O – laughing gas).

CO_2 emissions have been increasingly continually as a result of increasing fuel consumption from increasing air transports. Due to the availability of new data, changes in emission factors are required as of 1999; considerable changes in emissions result in turn. As of 2000, NMVOC, NO_2 and CO emissions levels have been lower, and N_2O levels higher, than the corresponding levels in 1999.

The CSE has no sub-categories under source category 1.A.3a Civil aviation.

3.1.5.1.2 Methodological issues (1.A.3.a)

No data is available relative to the flight movements, broken down for various flight phases, of aircraft operating in Germany. For this reason, the requirements for the Tier 2 method, calling for differentiation of emission factors for the LTO cycle and cruising flight, cannot be met. According to preliminary information from the EUROCONTROL European Organisation for the Safety of Air Navigation, as of 2006 EUROCONTROL will provide emissions data based on use of higher-tier methods.

In the NIR 2006, air transport emissions are still calculated via the Tier 1 method, pursuant to equation 2.7 of IPCC GPG p. 2.57 (IPCC, 2000):

Emissions = fuel consumption * emission factor

The energy balance prepared on the basis of aircraft fuel sold in Germany provides the basis for the relevant activity data. The emission factor for carbon dioxide was derived on the basis of the carbon content of kerosine. Until 1999, an emission factor of 3,299.7 g/kg (74,000 kg/kJ) was used; subsequently, a value of 3,150 g/kg (73,256 kg/kJ) was used, in keeping with the derived mean carbon content of kerosine.

Emissions of sulphur dioxide depend exclusively on the sulphur content of the fuel in question. On the other hand, the sulphur content is subject to regional fluctuations. For reasons of consistency, this content is determined by the Federal Environmental Agency transport section that provides all fuel-relevant indexes (these were last provided in September 2004). Pursuant to measurements carried out in 1998, the sulphur concentration in fuel is about 210 ppm, i.e. 0.021 mass-percent (DÖPELHEUER, 2002). According to Shell AG (Germany) and the Association of the German Petroleum Industry (deutscher Mineralölwirtschaftsverband; MWV), the sulphur content of kerosine is on the order of that of low-sulphur diesel fuel – no precise, generally valid relevant data was provided, however. Since the strong reduction of the sulphur content in refinery fuel streams will also have positive influences or secondary impacts on kerosine, a kerosine sulphur content of 210 mg/kg is assumed. Assuming complete combustion, this results in an emission factor of 0.4 g/kg; this is the value that will be used in future. For the reader's information, it should be added that a small part of emitted sulphur dioxide is further oxidised into SO_3 which, in turn, reacts with water to form sulphuric acid. The values listed in the IPCC guidelines, 1.0 g/kg for cruising flight and 2.4 g/kg for the LTO cycle, are not considered up to date.

Until 1999, emission factors for other pollutants were determined on the basis of the research project "Determination of exhaust emissions from air traffic over the Federal Republic of Germany" ("Ermittlung der Abgasemissionen aus dem Flugverkehr über der Bundesrepublik Deutschland", Federal Environmental Agency, 1989) via backward calculation from emissions.

From the study "Federal Environmental Agency texts 17/01" (UBA-Texte 17/01 (Federal Environmental Agency, 2001a), the ratio between national and international air transports was determined as 20 % to 80 %. The smaller percentage is based on the number of passengers, as a percentage of all passengers, who must be assigned to intra-German air transports (including transfers, base year 1995). In keeping with this relationship, 20 % of the total emissions determined are assigned to national civil air transports.

Table 23 shows the emission factors used to date. The first emission-factor column uses the units g/kg fuel, which is customarily used in the air-transport sector, while the second emissions-factor column uses the units kg/TJ, which are commonly used in the framework of reporting. For purposes of emissions reporting, the determined emission factors must be converted into the corresponding energy equivalents, taking the calorific value of kerosine into account. The Table shows the values used to date (until 2003).

Table 23: Emission factors used until NIR 2003

Name	Emission factor [g/kg]	Emission factor [kg/TJ]
Sulphur dioxide	0,2	4,7
Nitrogen dioxide	17,4	390
Volatile organic compounds (without methane)	2,6	59
Methane	0,04	1
Carbon monoxide	17,4	390
Carbon dioxide	3.299,7	74000
Nitrous oxide (laughing gas)	0,1	1,5

3.1.5.1.3 Uncertainties and time-series consistency (1.A.3.a)

Simply for scientific reasons, it is not possible to reliably determine the uncertainties for the emission factors used. The uncertainties in the emission factors for methane and nitrous oxide are +/- 200%. Experts place the uncertainty in the carbon-dioxide emission factors at 5%. Beginning next year, more precise emissions data, based on more precise calculation for Tier 2 methods (in some cases, even Tier 3), is expected from the EUROCONTROL European Organisation for the Safety of Air Navigation. As of that time, therefore, it will become possible to provide uncertainty ranges.

3.1.5.1.4 Source-specific quality assurance / control and verification (1.A.3.a)

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 for conversion into energy-related emission factors. No data is available to quantify a more accurate breakdown between national and international air transports. The IPCC's proposed emission factors were taken into account in the following considerations. On the other hand, it must be noted that the proposed emission factors were generated with an average fleet that does not reflect German air transports. The results of the verification will serve as the basis for future, planned improvements.

Already for the NIR 2005, the emission factors used for determination of air-transport emissions had to be revised and adjusted in keeping with new information that had become available and with technological progress in aircraft engines. As described above, combustion takes place at a range of different altitudes, and thus generation of emission factors can be problematic; emission factors for higher altitudes must be correlated with the emission factors determined for the LTO cycle (landing/take-off cycle, i.e. flight movements to an altitude of 3,000 feet, or about 915 m). For example, formation of nitrogen oxides depends strongly on external conditions and on the conditions in the combustion chamber, which change with altitude.

Profound changes have occurred in connection with emissions of ***nitrogen oxides***, since efforts to make aircraft engines more fuel-efficient have led to increases in average emission factors. On the other hand, in earlier studies the emission factors for cruising flight were overestimated, and this is reflected in the value in Table 3. Determining the emission factor for nitrous oxide has proven to be difficult (DÖPELHEUER, 2002; RAND, 2003; UBA, 2001a). At this juncture, it would be more correct to speak first of nitrogen oxides in general – i.e. of the sum of nitrogen monoxide and nitrogen dioxide. In an aircraft engine, primarily nitrogen monoxide is produced; this substance, after leaving the engine, is then converted into nitrogen dioxide. For this reason, the emission factor listed below refers to the totality of all nitrogen oxides, even where complete oxidation to nitrogen dioxide effectively occurs.

The primary source of the nitrogen is the nitrogen in the air, although organically bound nitrogen in fuel also plays a role. Formation of nitrogen oxides depends on the combustion-chambre intake temperature, the combustion-chambre intake pressure, the amount of time that hot gases remain in the combustion chambre and the local equivalence level of the fuel/air mixture. Aircraft engines can be divided into different type groups, in keeping with the range of different technologies that are currently in service. Three groups of engines are differentiated: with high, middle and low emissions levels (RAND, 2003).

At present, reliable values are available only from the ICAO database (ICAO, 2002). These values refer only to the LTO cycle, however. The cycle is used to determine whether engines comply with binding standards under international law (to date, standards have been defined for nitrogen oxides, CO, hydrocarbons and soot). The standards are certification standards, covering flight phases of specified duration and with specified thrust, as listed below (cf. Table 24).

Table 24: Reference-phase duration for engines, pursuant to ICAO

	Taxiing	Rolling for take-off	Climbing	Approach and landing	Total
Thrust	7 %	100 %	85 %	30 %	-
Duration	26:00	0:42	2:12	4:00	32:54

Derivation of cruising-flight emission factors from LTO-cycle emission factors requires correlation methods, such as the p^3-T^3 method which is used by the German Aerospace Association (Deutsches Zentrum für Luft- und Raumfahrt - DLR), and which is oriented to temperatures and pressures at the combustion-chambre intake. Engines with higher bypass ratios have slightly lower specific nitrogen-oxide emissions (DLR, 1999).

Aircraft with "high NO_X emissions" were found to have average NO_X emissions of about 14.5 g/kg, while those with "medium" NO_X emissions have about 13.5 g/kg and engines using technologies that provide "low" specific nitrogen-oxide emissions have about 11 g/kg (refers to values in the ICAO database, i.e. applies only to the LTO cycle) (RAND, 2003). Emission factors for NO_X, HC and CO, based on various different sources, are highly relevant in this context (IPCC, 1999). On the other hand, such factors are based on the base year 1992 and on forecasts for 2015.

The table below shows figures for the years 1992 and 2015 as provided by three different research institutions. All values successively provided by DLR, NASA (National Aeronautics and Space Administration) and ANCAT (Abatement of Nuisances from Civil Air Transport) refer to entire average flights, i.e. both the LTO range and cruising flight (cf. Table 25).

Table 25: NO_X emission factors for 1992 and 2015, from NASA, ANCAT and DLR, without military air transports (all flight phases)

	1992	**2015**
NASA	12,6	13,7
ANCAT	14,0	12,4
DLR	14,2	12,6

Source: IPCC 1999

It must be remembered that the average emission factors for NO_X have risen as a result of the increases, over the past few decades, in combustion-chambre pressures and temperatures. The values determined in the DLR and ANCAT scenarios are likely to have been affected by the assumption that a large percentage of engines in 2015 will have lower specific nitrogen oxide emissions, and thus the zenith in EI (NO_X) (emissions index = emission factor) will have been passed by then.

On the basis of 1995, an average worldwide EI (NO_X) of 13.0 g/kg can be assumed (UBA, 2001a). This value is based on calculations that the DLR carried out explicitly for this study, for certain flight profiles.

The following factors should be taken into account in specifying EI (NO_X):

- The mean estimate for 1992 is 13.6, while that for 1995 is 13.0.
- The EI(NO_X) has increased with respect to 1992, as a result of the increased combustion-chambre pressures and temperatures of the "average fleet". The "LTO average" of the majority of the world's current aircraft fleet is thus about 14.5 (RAND, 2003). The percentage of engines with very low specific nitrogen oxide emissions is still low.

Consequently, a mean EI (NO_X) of about 14.0 g/kg can currently be assumed. The values given in the IPCC Reference Manual (IPCC 1996b, p. 1.96) are considered to be too high for Germany. The primary reason for this is that the average value was determined using aircraft types (and, thus, engine types) that do not reflect the current fleet operating on intra-German routes. Furthermore, the underlying data used by the IPCC is comparatively old.

Unburned ***hydrocarbons***, along with carbon monoxide, are among the main products resulting from incomplete combustion of kerosine. Hydrocarbons are emitted primarily at low thrust levels. As engine efficiencies have improved, a process that has involved increases in combustion-chambre temperatures and pressures, the specific emission factor for unburned hydrocarbons has decreased. For example, the EI (HC) for global airline transports in 1986, for all flight phases, is given as 1.34 g/kg, while that for 1989 is 1.25 g/kg and that for 1992 is 1.12 g/kg (DLR, 1999). Studies of emitted hydrocarbons have shown that the size of hydrocarbon fractions formed in kerosine combustion decreases with increasing engine thrust. At 80 % thrust, primarily C1-C2 fractions form, while at 7 % and 30 % thrust maximum emissions of molecules with C2 and C3 fractions occur. On the other hand, at lower thrust levels, larger numbers of considerably longer hydrocarbon fractions occur. The emission factor varies considerably from thrust level to thrust level. For example, in a test run with the TF-39-1C engine, it was 18.9 g/kg at 7 % thrust and only 0.04 g/kg at 80 % thrust. The higher the thrust level, the higher the ratio of alkanes to alkenes; aromates range between 3 and 9 %, while oxygen-containing hydrocarbons account for about 25 % (DÖPELHEUER, 2002).

In *Aviation and the Global Atmosphere, Chap. 9, Aircraft Emissions*, the IPCC lists NASA values for emission factors, for various years (all flight phases) (IPCC, 1999). The values refer to all air traffic worldwide, except for military air traffic. According to this source, in 1976 the EI (HC) was 5.1 g/kg, in 1984 it was 3.3 g/kg and in 1992 it was 2.3 g/kg. An average value of 1.0 g/kg is forecast for 2015. Since engine efficiency has been improving smoothly and continuously, without major jumps, and since the level of EI (HC) is inversely proportional to such efficiency, the average of the 1992 and 2015 values may justifiably be used as the current report value. As a result, a current EI (HC) of 1.65 g/kg is assumed for hydrocarbons with methane.

On the other hand, this includes the C1-body fraction, in addition to the larger hydrocarbon fractions. If the species in question is not a radical one, and a pure hydrocarbon is involved, this group also includes methane. To determine the methane percentage, one would have to calculate back to methane on the basis of the average load level, and of other factors – a complicated procedure due to the methodological difficulties involved. In general, therefore, no reliable scientific basis is currently available for determining EI (CH_4) precisely. On the other hand, the European PARTEMIS (Measurement and prediction of emissions of aerosols and gaseous precursors from gas turbine engines) project includes chromatographic studies of emitted hydrocarbon species that support conclusions regarding the emission factor of methane. The results, which will soon be published, may well make it possible to provide a more precise value.

In the mid-1990s, some measurements made with one Pratt & Whitney engine (PW 305) and one Rolls Royce engine (RB211) were published (WIESEN et al, 1994 and 1996).

Taking the available information into account, an ***emission factor of 0.04 g/kg may be assumed for methane***. Methane is already included in the aforementioned figure for hydrocarbons, however. ***The mean EI for NMVOC must thus be given as 1.61 g/kg***.

Carbon monoxide results from incomplete carbon oxidation in combustion of kerosine. While the first sub-reaction involved, oxidation of carbon to carbon monoxide, is fast, the second sub-reaction, oxidation to carbon dioxide, determines the rate of the overall reaction. In combustion, part of the carbon monoxide is not completely converted.

Using a procedure similar to that used for HC, the IPCC gives an average emission factor for CO for four different years, and for all flight phases (LTO and cruising flight) (IPCC, 1999). According to the IPCC, the factor, also taking military air traffic into account, was 19.7 g/kg in 1976, 15.2 g/kg in 1984 and 11.3 g/kg in 1992. For the year 2015, NASA forecasts a value of 7.1 g/kg (IPCC, 1999). Since a continuous, largely linear decrease is also apparent in this area as well, the average of the 1992 and 2015 figures may again be taken as the current EI (CO). ***An EI figure for CO of 9.2 g/kg is thus assumed.***

Since ***carbon dioxide*** is of predominant importance among emissions, in terms of amount, care must be taken to obtain the most precise emission factor possible (DÖPELHEUER, 2002). The basis for determining the emission factor for kerosine consists of the average composition of this fuel. Kerosine consists of alkanes (about 35 % by volume), cycloalkanes (about 45 % by volume), aromates (about 17 % by volume) and alkenes (about 1 % by volume). As a rule, the fuel's composition varies widely by region. Among the lengths of the hydrocarbon chains involved, the fraction with 11 to 12 carbon atoms predominates by amount. Taking into account kerosine's average hydrogen content, and its average mol-weight of 176 kg/mol, kerosine can be simply described via the sum formula $C_{12}H_{23}$. In complete combustion, in strict stoichiometric terms, one kg of kerosine produces 1.24 kg of water and 3.15 kg of carbon dioxide. ***The average carbon-dioxide emission factor for kerosine may thus be assumed as 3,150 g/kg.*** This value has also been confirmed in numerous publications (including IPCC, 1999).

Nitrous oxide is also a product of nitrogen oxidation in the combustion chamber, and it can occur in traces. The literature contains very little data on this substance. The substance has also been measured in the PARTEMIS project, the results of which have not yet been published. As described above in connection with methane, in the mid-1990s measurements were published for nitrous oxide and methane, obtained during a study of a Pratt & Whitney engine (PW 305) and a Rolls Royce engine (RB211), and measured with infrared spectroscopy under various flight conditions (Wiesen et al, 1994 and 1996). These studies yielded an ***average emission factor of 0.15 g/kg for*** N_2O. In general, it must be assumed that more N_2O is produced in the combustion chamber than ammonia, since N_2O is a product with a medium oxidation level. Currently, a factor of 0.1 g/kg is being used in calculations. A value of 0.32 g/kg is used in the TREMOD framework. All in all, a value of 0.15 g/kg, as given in the above publications, seems plausible.

The customary breakdown for determining the contribution made by domestic air traffic to total emissions (DESTATIS, Fachserie 8, Reihe 6, 2002c) was obtained by allocating 80 % of determined total emissions to international air traffic. This breakdown is based on a study carried out by the TÜV technical control association, under commission to the Federal Environmental Agency (UBA, 1989). Since then, air traffic has become more and more international, and thus the domestic share of air traffic has become relatively smaller.

The breakdown must be based on the relevant IPCC guidelines' definition for preparation of national emissions inventories. Pursuant to those guidelines, domestic air traffic includes all passenger and cargo flights that start and end on the territory of a single country. International air traffic comprises all civil air traffic that originates in other countries or that leaves the relevant country's national territory.

Domestic air travel accounted for 11.9 % of all the passengers that moved through German airports in 2002. A total of 114 million passengers were transported; of these, 13.6 million fell within the category *domestic air travel*. Including all transfer passengers, however, a total of 19.8 million passengers, or 17.4 % of all passengers, flew on intra-German routes in 2002. Under the IPCC's definitions, transfer passengers must be included, as a rule. In the area of cargo traffic, international flights accounted for 2.1 million of the total of 2.2 million t of freight transported in 2002. The national / domestic share was thus 4.5 %.

As to overall numbers of flights, in 2002 a total of 1.45 million flights were made in Germany, of which 0.339 million had destinations within Germany. This number represents a share of 23.4 %.

Another category that can be useful for calculating domestic shares of total transports, for purposes of calculating emissions, is that of seat/tonne-km. Here as well, no close correlation to fuel consumption may be assumed. The reasons for this include variances in fleet fuel consumption, and the relatively large fuel consumption during the LTO cycle, especially during take-off and climbing. Air freight accounted for 23.8 % of total transport performance (assuming 0.1 tkm to be equivalent to one seat-km). A total of 7.81 billion tonne-kilometers were found to have been completed in 2002. National flights accounted for 21.4 % of all passenger seat-km in 2002. The combined figure for freight and passenger km together is smaller, since most freight transports – as described above – serve international destinations.

At present, no calculation procedure is available for converting existing data into fuel-consumption figures, and no data that would support such conversion is collected; consequently, a 20 % domestic air transport share will continue to be assumed for calculation purposes. The smaller percentage is based on the number of passengers, as a percentage of all passengers, who must be assigned to intra-German air transports (including transfers, base year 1995) (UBA, 2001a). While the data on passengers, flights and seat-km for 2002 also points to this share, no correlation with fuel consumption can be derived, and such a correlation should actually be used as a calculation basis.

3.1.5.1.5 Source-specific recalculations (1.A.3.a)

The same emission factors are used as were used in the NIR 2005. Recalculation is thus not required.

3.1.5.1.6 Planned improvements (source-specific) (1.A.3.a)

In a first step, the emission factors used until the year 2000 were used for calculations in the CSE. These emission factors are still valid at present. Next year, EUROCONTROL is to provide emissions data for the EU Member States. Plans call for using this data, following review, in emissions reporting next year. This will place reporting on the basis of an improved method. The data is then also to be used for recalculation of years reported to date.

The emission factors used for the last five years, and for the period prior to those years, are shown again in Table 26.

Table 26: Adjusted emission factors for civil air transports

Name **Year**	**New emission factor 2000-2004 [g/kg]**	**New emission factor 2000-2004 [kg/TJ]**	**Old emission factor 1990-1999 [kg/TJ]**
Nitrogen dioxide	14,00	325,58	390
Volatile organic compounds (without methane)	1,61	37,44	59
Methane	0,04	0,93	1
Carbon monoxide	9,20	213,95	390
Carbon dioxide	3.150,00	73.265	74.000
Nitrous oxide (laughing gas)	0,15	3,49	1,5

3.1.5.2 Transport - Road transportation (1.A.3.b)

3.1.5.2.1 Source-category description (1.A.3.b)

CRF 1.A.3.b					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
All Fuels	l / t	CO_2	11,82 %	15,25 %	rising

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	CS	CS/M	-	-	-	CS/M	CS/M	CS/M	CS/M	CS/M
EF uncertainties in %	-	-	-	-	-	-				
Distribution of uncertainties	-	-	-	-	-	-				
Method of EF determination	T 3	T 3	T 3	T 3	T 3	T 3				

Road transports are a key category for CO_2 emissions from gasoline and diesel fuel, in terms of emissions levels and trend.

Emissions from motorised road traffic in Germany are reported under this category. It includes traffic on public roads within Germany, excluding agriculture and forestry and excluding the military. Calculations are made for the vehicle categories of passenger cars, motorcycles, light duty vehicles, heavy duty vehicles and buses. For calculation purposes, the vehicle categories are broken down into so-called *vehicle layers* with the same emissions behaviour. To this end, the vehicle categories are divided by type of fuel used, vehicle size (utility vehicles / buses: weight class; passenger car / motorcycles: engine displacement) and installed pollution control equipment pursuant to EU directives on emissions legislation ("EURO norms") and traffic-location region (outside of municipalities, within municipalities, and autobahn).

Since 1990, emissions of CH_4, NO_X, CO, NMVOC and SO_2 from road transportation have decreased sharply, due to catalytic-converter use and engine improvements resulting from continual tightening of emissions laws, and due to improved fuel quality (cf. Table 27, p. 137).

The sharp reduction in the methane emission factor for gasoline and, thus, the sharp reduction in methane emissions between 1990 and 1993, is due especially to a drastic reduction in the numbers of vehicles with two-stroke engines in the new German Länder. Further reductions, until 2003, resulted from the aforementioned tightening of emissions standards.

For busses and heavy trucks (over 3.5 t total permissible vehicle weight), maximum permissible levels of hydrocarbon (HC) emissions were lowered especially sharply (-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 fuel

– 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. For this reason, the decreasing trend in N_2O emissions that has been observed since 2000 can be expected to continue. In past years, reporting was based on vehicle-specific N_2O emission factors that were derived from the relevant literature and that did not permit any differentiation by road categories. In the meantime, a number of additional studies have been carried out (TNO 2002a, TNO 2002b, TNO 2003) that have made it possible to differentiate factors by specific road types. These studies have shown that the factors used to date have been considerably too high in some cases (cf. INFAS 2004). As a result of use of updated emission factors, the current report shows lower N_2O emissions for the entire 1990-2003 period than were reported in the 2005 reporting year. It is still the case that only a limited empirical basis is available for the N_2O emission factors, however.

CO_2 emissions depend directly on fuel consumption. From 1990-1999, these emissions increased, since growth in miles travelled outweighed improvements in vehicle fuel consumption. Prior to the year 2000, CO_2 emissions showed only an increasing trend in the transport sector. Since that year, a first marked trend reversal has been seen, however. In 2004, CO_2 emissions in the transport sector were about 15 million t lower than they were in 2000. The likely reasons for this trend include reductions in specific fuel consumption, a marked shifting toward diesel vehicles in new registrations, effects resulting from the "Ökosteuer" ecologically based fuel tax – and consumers' growing tendency to travel to other countries in order to make their fuel purchases.

According to preliminary calculations, CO_2 emissions in 2004 were up slightly (+0.4 %) from the previous year.

Table 27: Road-transportation emissions

[Gg]	CO_2	CH_4	N_2O	NO_X	CO	NMVOC	SO_2
1990	150.357,76	60,5275996	1,9653016	1343,22322	6526,71437	1408,98847	90,2013207
2000	171.288,79	15,6981775	4,81041077	999,765889	2464,98082	279,063762	19,6437997
2002	165.960,30	12,4159083	4,49964584	855,738908	2048,75864	219,025844	3,4519057
2003	159.827,46	10,5407856	4,18109799	776,565416	1859,16917	186,659618	0,82293694
2004	160.408,90	9,51918616	4,06947767	732,249454	1700,3552	168,560428	0,82843982

In source category 1.A.3b Road transportation, the CSE includes mopeds, motorcycles, diesel-powered automobiles, gasoline-powered automobiles, buses, light duty vehicles with diesel and petrol engines and heavy duty vehicles, broken down by emissions-reduction equipment.

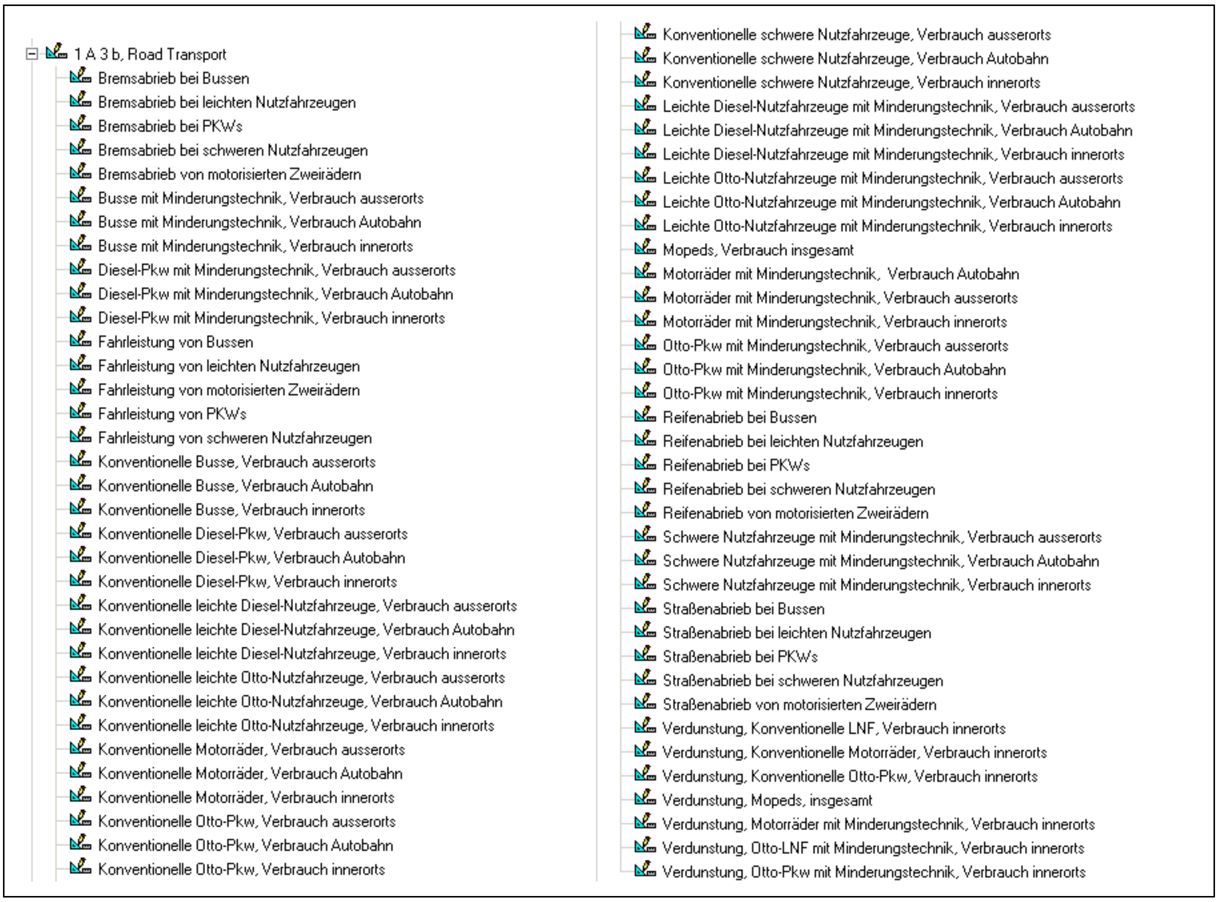


Figure 21: Structural allocation, 1.A.3b Road transportation

3.1.5.2.2 Methodological issues (1.A.3.b)

Calculation of CO_2 emissions from motorised road transports in Germany is based on a *top-down* approach (Tier 1 procedure) based on the amount of fuel sold in Germany. The data in this respect is available in the form of *energy balances*. In order to determine the CO_2 emissions, the individual fuel consumption figures (petrol, diesel (not including biodiesel), LP gas) are multiplied by country-specific CO_2 emission factors.

Non-CO_2 emissions are calculated with the aid of the TREMOD model ("Transport Emission Estimation Model"; IFEU, 2005)[14]. TREMOD adopts a "*bottom-up*" (Tier 3) approach whereby mileage of the individual vehicle layers is multiplied by region-specific emission factors. For passenger cars and light duty vehicles, in addition, a "*cold start surplus*" is added. The total consumption calculated on the basis of fuel type is compared with the consumption according to the energy balance. The emissions are corrected with the aid of factors obtained from this comparison process. For petrol-powered vehicles, the evaporation emissions of VOC are calculated in keeping with the reduction technology used.

From the emissions and fuel consumption for the various vehicle layers, aggregated, fuel-based emission factors are derived (kg of emissions per fuel consumption, in TJ) and then forwarded to the CSE via a relevant interface (cf. Chapter 17.3.2). In keeping with the CORINAIR report structure, these factors are differentiated only by type of fuel, type of road (autobahn, rural road, city road) and, within the vehicle categories, by "without/with pollution-

14 To permit derivation and evaluation of reduction measures, TREMOD is also used to calculate the energy consumption and CO_2 emissions of the individual vehicle categories. The values are subsequently aligned with total consumption and total emissions of CO_2.

control equipment". The following differentiation is used in the area of pollution-control equipment:

	Without pollution-control equipment	**With pollution-control equipment**
Passenger cars / light commercial vehicles with petrol-burning engines	without 3-way catalytic converters	with 3-way catalytic converters
Passenger cars / light duty vehicles with diesel engines, buses, heavy commercial vehicles, motorcycles	prior to Euro 1	after Euro 1

For calculation with TREMOD, extensive basic data from generally accessible statistics and special surveys was used, co-ordinated, and supplemented. An overview of the principal sources and key assumptions is given below. Detailed descriptions of the databases, including information on the sources used, and the calculation methods used in TREMOD, are provided in the aforementioned IFEU report.

Real data for the years 1990-2000

This real data refers to:

- Motor-vehicle ownership:
  For western Germany from 1990 to 1993, and for Germany as a whole from 1994, car ownership was calculated on the basis of the officially published ownership and new registration statistics of the Federal Motor Vehicle Agency (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.
- Emission factors:
  All emission factors are listed in the "Manual of road-traffic emissions 2.1" ("Handbuch für Emissionsfaktoren des Straßenverkehrs 1.2") (INFRAS, 2004). This manual was prepared in the framework of co-operation between Germany, Switzerland, Austria and the Netherlands in derivation of emission factors for road traffic. The emission factors in the manual originate predominantly from the measurement programmes of TÜV Rheinland (TÜV = Technical Control Association) and RWTÜV. These include fundamental surveys for the reference years 1989/1990. In these surveys, a new method was used, for both passenger cars and heavy duty vehicles, whereby emission factors were derived according to driving conduct and the traffic situation. Within the context of field monitoring data, the passenger car emission factors were updated for cars produced up to 1994. Version 2.1 of the "Manual of road-traffic emission factors" ("Handbuch Emissionsfaktoren des Straßenverkehrs"), which was used for current emissions calculations, draws on findings of the COST 346 EU working group and the ARTEMIS research programme. It features the following important substantial changes over the earlier version, 1.2:

Automobiles:

- Emission factors on the basis of emissions measurements (instead of estimates) through EURO3 (gasoline-powered) and EURO2 (diesel-powered)
- The "cold-start surplus" now has dependencies on the outside (i.e. ambient) temperature, for gasoline-powered EURO2 automobiles.

Light duty vehicles:

- Differentiation of three size classes (previously, no differentiation)

- Now all emission factors are listed for a mean load level of 30 % (previously, 0%).
- New emissions measurements (instead of estimates) through EURO2 (gasoline-powered) and EURO1 (diesel-powered)
- The "cold-start surplus" now has dependencies on the outside (i.e. ambient) temperature for gasoline-powered EURO2 light duty vehicles.

Heavy duty vehicles/busses:

- Measurements of engine operating parameters, for EURO1-3
- Revision of methods for deriving emission factors, for all emissions-reduction concepts, pursuant to methods of TU Graz (TU Graz 2002/2003)

Motorbikes/motorscooters/motorcycles:

- Revision of methods for deriving emission factors, for all emissions-reduction concepts, pursuant to methods of RWTÜV (RWTÜV 2003)
- Mileage:
  The principal source is the time series of domestic mileage of individual vehicle categories which is published continuously in "*Verkehr in Zahlen*" ("Traffic in Figures") (DIW). This time series has been completely revised on the basis of results of the "vehicle mileage survey" ("Fahrleistungserhebung 2002"; IVT 2004). In differentiated mileage surveys conducted on behalf of the Federal Ministry of Transport for the years 1990 and 1993, special TREMOD requirements were taken into account: For example, the breakdown of mileage according to vehicle types and road characteristics corresponds to the differentiations used as a basis in emissions measurement programmes. Vehicle-category-specific domestic mileages for the TREMOD model are derived with the help of differentiated data from the 1990,1993 and 2002 vehicle-mileage surveys, and with key domestic mileage data pursuant to "Traffic in Figures" ("Verkehr in Zahlen").
- Data for the years 2001 to 2004

This real data refers to:

- Development of the road traffic fleet:
  Fleet data for the TREMOD model, as of the 2001 reference year, is the result of cross-checking with the database of the Federal Motor Vehicle Agency (KBA). Such cross-checking provides vehicle-fleet statistics for each reference year, broken down as is needed for emissions calculation – by the characteristics of engine type (gasoline, diesel, other), size class, vehicle age and basic emissions classification. For each reference year, the mid-year fleet is assumed to be representative of the fleet's composition for the year.
- Emission factors:
  The emission factors are derived from the development in the numbers of vehicles within the individual vehicle layers. The emissions reduction achieved via the introduction of sulphur-free fuels was estimated by the Federal Environmental Agency.
- Mileage:
  Vehicle mileage was updated on the basis of the "2002 vehicle mileage survey" ("Fahrleistungserhebung 2002"; IVT 2004).

3.1.5.2.3 Uncertainties and time-series consistency (1.A.3.b)

No studies of the relevant data uncertainties have yet been carried out.

3.1.5.2.4 Source-specific quality assurance / control and verification (1.A.3.b)

Quality checking of the data is achieved by comparing energy consumption based on the top-down approach (Energy Balance) and bottom-up approach (uncorrected TREMOD results). For petrol/gasoline, deviations of between 3.5 % and 7.0 % were calculated for the period 1994-2002. The deviations for diesel-fuel consumption ranged between 3.4 % and 10.3 %.

3.1.5.2.5 Source-specific recalculations (1.A.3.b)

The presented emissions data was calculated with TREMOD version 4.0 (IFEU, 2005). With this version, the following changes, with respect to the 2005 report year, have been made in the database:

- Cross-checking of data on consumption of gasoline, diesel fuel, petroleum and LP gas, in the years 2000-2004, with the 2000-2001 preliminary Energy Balances; and with the official petroleum data of the Federal Office of Economics and Export Control (BAFA) and sales data of the Mineralölwirtschaftsverband petroleum-industry association for the years 2003-2004
- Inclusion of updated emission factors, pursuant to Version 2.1 of the "Manual of road-traffic emissions" ("Handbuch für Emissionsfaktoren des Straßenverkehrs")
- Inclusion of new vehicle-mileage time series pursuant to "Traffic in Figures" ("Verkehr in Zahlen") and to the results of the "2002 vehicle mileage survey" ("Fahrleistungserhebung 2002")

The TREMOD model is designed to recalculate the entire relevant time series when basic data changes.

In addition, the area of lubricants in the road-transporation sector was included for the first time.

3.1.5.2.6 Planned improvements (source-specific) (1.A.3.b)

Both activity data and emission factors are subject to a constant revision process. An update of vehicle-mileage data in keeping with the latest data from "Traffic in Figures" ("Verkehr in Zahlen") is expected for the next report. With regard to emission factors, new data will be obtained, in so-called "field monitoring", for late-model automobiles (EURO 3 / EURO 4); this data will enter into relevant emissions calculation.

3.1.5.3 Transport - Railways (1.A.3.c)

3.1.5.3.1 Source-category description (1.A.3.c)

CRF 1.A.3.c					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
1.A.3.c Transport Railways					
	- / -				

Gas	**CO_2**	**CH_4**	**HFCHFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	CS	CS	--	--	--	CS				
EF uncertainties in %	--	--	--	--	--	--				
Distribution of uncertainties	--	--	--	--	--	--				
Method of EF determination	T1	T1	--	--	--	T1				

Railways transports are not a key category.

Germany's railway sector is undergoing a long-term modernisation process, aimed at making electricity the main energy source for rail transports. Use of electric traction has continually been increased, and now electric traction accounts for 80 % of all traction energy (with diesel traction accounting for the rest)[15]. Railways' power stations for generation of traction current are allocated to the stationary component of the energy sector (1.A.1.a) and are not included in further description below.

In energy input for trains of German Railways (Deutsche Bahn AG), diesel fuel is the only energy source that plays a significant role apart from electric power. Solid fuels are used for historical rail vehicles – in the main, steam locomotives are operated for demonstration and exhibition purposes. The amounts of hard-coal and lignite used in historical railway vehicles vary from year to year. As a result, the CO_2 emission factors for railway use of solid fuels also differ from year to year. Such fuels are of little significance, accounting for only 1.5 % of total energy inputs in the railway sector. Use of other fuels – such as vegetable oils or gas – in private narrow-gauge railway vehicles has not been included to date and may still be considered negligible.

Source category 1.A.3c Railways is included as a separate category in the CSE.

Figure 22: Structural allocation, 1.A.3c Railways

3.1.5.3.2 Methodological issues (1.A.3.c)

No specific information relative to this source category is found in IPCC Good Practice Guidance (2000: Chapter 2). 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 1 method and the basic calculation rule pursuant to equation 2.6 of the IPCC Good Practice Guidance (2000, p. 2.46).

The energy-consumption data is taken from the *Energy Balance* (AGEB, 2003) and, for the years 2003-2004, from sales statistics of the Mineralölwirtschaftsverband petroleum-industry

[15] from Energiewirtschaftliche Tagesfragen, 54th year (2004), issue 3, p. 185

association. In particular, the fuel data has been taken from the following Energy Balance lines, for the following periods:

Table 28: Sources for AR in 1A3c

Fuel type	Energy Balance line	Relevant years
Diesel fuel	74	until 1994
	61	as of 1995
Lignite briquettes	61	as of 1996
Crude lignite	61	as of 1996
Hard coal	74	until 1994
	61	as of 1995
Hard-coal coke	61	as of 1995

The emission factors are based, for each specific gas, on the results of various Federal Environmental Agency research projects and expert opinions:

- For CO_2, the reader's attention is called to the documentation in Annex 2, Chapter CO_2 emission factors.
- The CH_4 EF for solid fuels are based on the Federal Environmental Agency study "Luftreinhaltung '88" ("Air Quality Control '88", UBA, 1989b). These country-specific factors can be compared with the IPCC default values: for coal, the EF used are higher than those in the IPCC Reference Manual (1996b, Table 1-7). For diesel fuel, a new procedure will be used beginning this reporting year. Specific emission factors have been derived for all diesel locomotives in service in Germany. Emissions calculations are being converted to a procedure that links such locomotive-model-specific emission factors with relevant operational mileage (kilometres travelled) for the relevant year ("Transport Emission Estimation Model"; IFEU, 2005.) The default value in the IPCC Reference Manual (1996b, Table 1-7) is higher than the country-specific emission factors used by Germany, which take account, via a chronological progression, of engine-based measures to improve the emissions behaviour of railway vehicles (1995: 2.6 kg/TJ 2004: 1.6 kg/TJ)
- As to the emission factor for N_2O, the Federal Environmental Agency's experts agree with the Federal Environmental Agency study "Luftreinhaltung '88" (UBA, 1989b). The country-specific EF are considerably higher than the corresponding values in the IPCC Reference Manual (1996b, Table 1-8).

Table 29: Comparison of current EF for railway transports with the corresponding default emission factors

Gas	Emission factor used [kg/TJ]	Default emission factor [kg/TJ]
CH_4	Diesel fuel: 1.6 – 3.2 Hard coal: 15.0 Lignite briquettes: 15.0 Crude lignite: 15.0 Hard-coal coke: 0,5	Oil: 5 Coal: 10
N_2O	Diesel fuel: 1.0 Hard coal: 4.0 Lignite briquettes: 3.5 Crude lignite: 3.5 Hard-coal coke: 4,0	Oil: 0.6 Coal: 1,4

Source: Luftreinhaltung `88 (UBA, 1989b)

3.1.5.3.3 Uncertainties and time-series consistency (1.A.3.c)

No studies have yet been carried out of the data uncertainties for this source category. The AR 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.

3.1.5.3.4 Source-specific quality assurance / control and verification (1.A.3.c)

The old emission factors have been properly supplanted. No further verification is planned at present. For reporting, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents.

3.1.5.3.5 Source-specific recalculations (1.A.3.c)

The 1990-2003 time series has been completely recalculated, using the new emission factors for CH_4 and N_2O.

3.1.5.3.6 Planned improvements (source-specific) (1.A.3.c)

In future, specific emission factors will be derived for all diesel locomotives used in Germany's railway sector. The emission calculations are being converted to a technique which links these type-specific emission factors to the corresponding operational outputs (kilometres travelled).

3.1.5.4 Transport - Navigation (1.A.3.d)

3.1.5.4.1 Source-category description (1.A.3.d)

CRF 1.A.3					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
Transport Navigation 1.A.3.c					
	- / -				

Gas	**CO_2**	**CH_4**	**HFCHFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	CS	CS	--	--	--	CS				
EF uncertainties in %	--	--	--	--	--	--				
Distribution of uncertainties	--	--	--	--	--	--				
Method of EF determination	T1	T1	--	--	--	T1				

Navigation is not a key category.

Navigation is broken down primarily into the categories "coastal and inland navigation" and "marine transport". All domestic navigation is diesel-powered, while heavy fuel oil is also used in the international shipping sector. Emissions from international navigation are listed in the emissions inventories, as a memo item, but they are not included in total emissions.

The importance of Germany's navigation sector derives from Germany's network of waterways. The German Federal Water and Maritime Administration (WSV) notes in this connection[16]: "The waterway network, although much less dense than the country's railway and road networks, is still a contiguous network that links the country's major seaports with

[16] http://www.wsv.de/Wasserstrassen/Wasserstrassen.html, last revision, 7 June 2002

the high seas and with inland areas and that interconnects the country's most important industrial centres. Most of Germany's large cities are connected to the waterway network. The Federal waterway network has a total of about 7,300 km of inland waterways and includes some 17,800 km² of maritime areas. Of the former, some 6,500 km are navigable inland waterways and about 750 km are maritime routes, not including the outer areas of seaward access routes.

Under source category 1.A.3d Navigation, the CSE includes coastal and inland fishing and coastal and inland shipping.

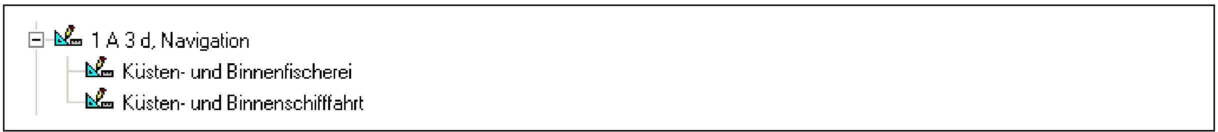


Figure 23: Structural allocation, 1.A.3d Navigation

3.1.5.4.2 Methodological issues (1.A.3.d)

The IPCC Good Practice Guidance (IPCC, 2000, page 2.52) specifies that, where data availability is good, the Tier 2 method is to be used, in connection with country-specific CO_2 emission factors and engine-specific EF for CH_4 and N_2O. If no engine-specific energy consumption data is available, then the IPCC default emission factors for CH_4 and N_2O may be used. Where country-specific emission factors for CO_2 are lacking, calculations may be carried out on the basis of the IPCC default emission factors, as long as the source in question is not a key category.

The IPCC Guidelines do not specify any methods for calculating emissions from military navigation. Good practice for the determination of such emissions calls for consulting military experts.

For Germany, emissions from this source category are calculated as the product of consumed fuels and country-specific emission factors for CO_2, CH_4 and N_2O. This procedure is in keeping with the general Tier 1 method and the basic calculation rule using the equation "emission factor times fuel consumption" pursuant to IPCC Guidance (2000: Chapter 2.4.1.1, p. 2.51).

The emission factors are based, for each specific gas, on the results of various Federal Environmental Agency research projects and expert opinions:

- With regard to the CO_2 emission factor for diesel fuel, 74,000 kg/TJ, and to that for heavy fuel oil, 78,000 kg/TJ, the reader's attention is called to the documentation in Annex 2 – the chapter on "CO_2 emission factors".
- The CH_4 emission factor for heavy heating oil, 3.0 kg/TJ, is based on the Federal Environmental Agency (UBA) "Air Quality Control '88" ("Luftreinhaltung '88"; (UBA, 1989b)). This value is lower than the IPCC default value for heavy heating oil in maritime navigation, 7 kg/TJ, as shown in the Reference Manual (IPCC et al, 1997, p. 1.90, Table 1-48). For diesel fuel, the emission factor for heavy duty vehicles without emissions-reduction equipment was used. A 15% reduction of specific CH_4 emissions in the 1990-2004 period, resulting from engine improvements, was assumed, in keeping with experts' expectations. The country-specific EF, at 2.4-2.8 kg/TJ, are also lower than the IPCC default value for diesel fuel, 5 kg/TJ, as listed in the Reference Manual (IPCC et al, 1997, p. 1.35, Table 1-7)

- The emission factors for N_2O, are in keeping with Federal Environmental Agency (UBA) experts' assessments based on the UBA study "Air Quality Control '88" ("Luftreinhaltung '88") and on analogies to heavy duty vehicles without emissions-reduction equipment. The country-specific EF for diesel fuel, at 1.0 kg/TJ, is higher than the value of 0.6 kg N_2O/TJ given by the Reference Manual (IPCC, 1997: Table 1-8). The EF for heavy heating oil, 3.5 kg/TJ, is nearly twice as high as the corresponding recommended value in the Reference Manual (IPCC et al, 1997: p. 1.90, Table 1-48).

The energy consumption data was taken from the *Energy Balance* (AGEB, 2003) and, for the years 2002-2004, from official petroleum data of the Federal Office of Economics and Export Control (BAFA). In particular, the fuel data has been taken from the following Energy Balance lines, for the following periods:

Table 30: Sources for AR in 1.A.3d

Fuel type	Energy Balance line	Area	Relevant years
Diesel fuel	6	international	all
	77	domestic	until 1994
	64	domestic	as of 1995
Heating fuel oil	6	international	all

The following section breaks down the activity rates into the areas of domestic and international, taking account of sales – as listed in different Energy Balance lines – of different ship fuels subject to different taxation rates. The resulting amounts of fuel, in combination with the various relevant EF, make it possible to calculate and list domestic and international emissions separately. Since no data is available on ship movements, the IPCC-GPG criteria for separating domestic and international emissions (2000: Table 2.8) cannot be used.

The majority of the fuel in question is sold for marine transport. Sales have been relatively constant. An increase has occurred in the years since 1999, although sales have not returned to their levels in 1990. Consumption in coastal and inland navigation has been decreasing, although the abrupt decrease in 1994/1995 was due solely to a conversion within the Energy Balance.

3.1.5.4.3 Uncertainties and time-series consistency (1.A.3.d)

No studies have yet been carried out of the data uncertainties for these source categories. The emission factors for CO_2 , CH_4 and N_2O are constant throughout the entire time series and, thus, are consistent.

The activity-data time series for coastal and inland shipping exhibit inconsistencies resulting from statistical conversion as of 1994/1995; these inconsistencies cannot be eliminated at present.

3.1.5.4.4 Source-specific quality assurance / control and verification (1.A.3.d)

Source-specific verification was carried out via a comparison between the emission factors used and the newly obtained country-specific emission factors. The old emission factors have been properly supplanted. No further verification is planned at present.

3.1.5.4.5 Source-specific recalculations (1.A.3.d)

At present, no information can be provided regarding future recalculations.

3.1.5.4.6 Planned improvements (source-specific) (1.A.3.d)

No improvements are planned at present.

3.1.5.5 Transport - Other transportation (1.A.3.e)

3.1.5.5.1 Source-category description (1.A.3.e)

CRF 1.A.3.e					
Key category nach Level 8l) / Trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
Transport Other transportation 1.A.3.e					
Liquid fuels	l / -	CO_2	0,27	0,27	stag-nating

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	CS	CS	--	--	--	CS	--	--	--	--
EF uncertainties in %	--	--	--	--	--	--				
Distribution of uncertainties	--	--	--	--	--	--				
Method of EF determination	T1	T1	--	--	--	T1				

The source category "Other transportation" is a key category, in terms of emissions levels, for CO_2 emissions from liquid fuels.

Emissions from construction-related transports and from gas turbines in natural-gas-compressor stations are reported under this source category. Construction-related transports are a category within the Energy Balance. Gas turbines in natural-gas-compressor stations, on the other hand, are a clearly defined plant type.

In the CSE, construction-related transports and gas turbines in natural-gas-compressor stations are allocated to source category 1.A.3.e "Other transportation".

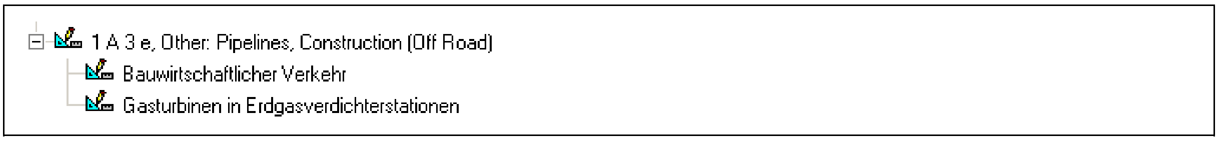


Figure 24: Structural allocation, 1.A.3.e Other transportation

3.1.5.5.2 Methodological issues (1.A.3.e)

The emissions for the aforementioned areas are calculated as the product of fuel consumption and the relevant country-specific emission factors. The IPCC Good Practice Guidance (2000) provides no specific provisions for "good practice" in connection with Other transportation. The selected procedure is in keeping with the general Tier 1 method as set forth, for example, in equation 2.3 of the IPCC Good Practice Guidance (2000: p. 2.37).

The area of *construction transports (Bauwirtschaftlicher Verkehr)* accounts for the greater share of energy inputs. The relevant energy-consumption data, for diesel fuel and petrol, are taken from Energy Balance lines 79 and 67, respectively (until 1994 and as of 1995). Since construction transports are significant to this category's status as a key category, the calculation procedure used for this category should be as detailed as possible. At present, due to a lack of detailed data, only the above-described Tier 1 method can be used, however.

The emission factors are based, for each specific gas, on the results of various Federal Environmental Agency research projects and expert opinions:

- For CO_2, the reader's attention is called to the documentation in Annex 2, Chapter CO_2 emission factors.
- The country-specific CH_4-EF is based on the Federal Environmental Agency study "Air Quality Control '88" ("Luftreinhaltung '88"; UBA 1989b). The country-specific N_2O emission factor of 1.0 kg/TJ was derived, by analogy, from the value for heavy duty vehicles without emissions-reduction equipment.

The area of *natural-gas-compressor stations* accounts for the smaller share of energy inputs. The relevant energy-consumption data for natural gas is taken from Energy Balance lines 8 and 40, respectively (until 1994 and as of 1995). Since this area is an insignificant sub-emissions area of the source category in question, the above-described Tier 1 method was used.

The emission factors are based, for each specific gas, on the results of various Federal Environmental Agency research projects and expert opinions:

- For CO_2, the reader's attention is called to the documentation in Annex 2, Chapter CO_2 emission factors.
- The CH_4 and N_2O EF have been taken from Chapter 4.9.5 and Annex E, Table 5 of the Federal Environmental Agency study on stationary combustion plants (RENTZ et al, 2002); the procedure used in the study is described in Chapter 3.1.1.2.

3.1.5.5.3 Uncertainties and time-series consistency (1.A.3.e)

As a result of statistical conversions in 1994/1995, the EF time series for CH_4 (for all fuels) and the EF time series for N_2O (for gasoline, construction industry) contain inconsistencies that cannot be eliminated. Since 1995, relevant activities in the new German Länder have not been listed separately. As a result, emissions cannot be calculated using new-Länder EF that diverge from those for the old German Länder. Since it cannot be assumed that specific emissions – and, thus, EF – were comparable in the old and new German Länder until 1994, the different EF for those years have been retained. As a result, the time series contains a methodological change, manifested as a jump in the overall EF (IEF).

The procedure for determining uncertainties for natural-gas-compressor stations is described in Chapter 3.1.1.2. Results for N_2O are presented in Chapter 3.1.1.3.2, while those for CH_4 are presented in Chapter 3.1.1.3.3 .

3.1.5.5.4 Source-specific quality assurance / control and verification (1.A.3.e)

At present, it is not possible to carry out more detailed source-specific quality assurance / control and verification.

The results of the general procedure for source-specific quality assurance / control and verification for the area of emission factors for natural-gas-compressor stations are described in Chapter 3.1.1.3.2. Last year, only a few, minor quality assurance measures were carried out; in the process, a number of transfer errors made in data entry were identified and corrected. In addition, a number of individual values for the years 2001 through 2004 were corrected (previously, the value for 2000 had been adopted for those years); now, as in the procedure for other emission-factor time series, the values for these years have been obtained via linear interpolation between the values for 2000 and the projected values for 2010 (cf. Chapter 3.1.1.2).

3.1.5.5.5 Source-specific recalculations (1.A.3.e)

With regard to emissions data for N_2O and CH_4 from natural-gas-compressor stations, recalculations have been completed for the current measures described in Chapter 3.1.1.4 (correction of emission factors).

No further recalculations were required.

3.1.5.5.6 Planned improvements (source-specific) (1.A.3.e)

Plans call for using updated, country-specific emission factors.

The planning described in Chapter 3.1.1.4 could further improve the already good data for natural-gas-compressor stations.

3.1.6 Other: Residential, commercial/institutional, agriculture, forestry and fishing (1.A.4)

3.1.6.1 Source-category description (1.A.4)

CRF 1.A.4					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
CRF 1.A.4.a (Commercial/Institutional)					
All Fuels	l / t	CO_2	5,03 %	4,44 %	falling
All Fuels	- / t	CH_4	0,10 %	0,01 %	falling
CRF 1.A.4.b (Residential)					
All Fuels	l / t	CO_2	10,19 %	11,00 %	rising
CRF 1.A.4.c (Agriculture/Forestry/Fisheries)					
All Fuels	l / t	CO_2	0,86 %	0,64 %	falling

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	CS	CS	NO	NO	NO	CS	CS	CS	CS	CS
EF uncertainties in % - liquid fuels		-25/ +50	-	-	-	± 35				
EF uncertainties in % - gaseous fuels		-50 / +100	-	-	-	± 35				
EF uncertainties in % - solid fuels		-50/ +100	-	-	-	± 50				
Distribution of uncertainties		L	-	-	-	N				
Method of EF determination		Tier 2	-	-	-	Tier 2				

Source category 1.A.4 (Other sectors) is a key category for CO_2, in all of its sub- source categories, for nearly all fuel categories and in terms of emissions levels or trend or both. Furthermore, the source category 1.A.4.a (*Commercial/Institutional*) is a key category, in terms of trend, for CH_4 emissions from solid fuels.

Source category 1.A.4 comprises combustion systems in the areas Residential, Commercial and Institutional and Agriculture, along with various mobile sources.

Heat-generation systems in small combustion systems of small commercial and institutional users (commerce and services) are reported under source category 1.A.4.a.

1.A.4.b comprises energy inputs in households (the Residential sector). This refers primarily to combustion systems. In addition, source category 1.A.4.b includes residential mobile sources (not including road transportation).

Sub- source category 1.A.4.c comprises the areas of agriculture, forestry and fisheries. Reporting under this category includes emissions from heat generation in small and medium-sized combustion systems and emissions from agricultural transports. Pursuant to the IPCC structure, 1.A.4.c also includes emissions from mobile sources in fisheries and in forestry. Such emissions cannot be reported in 1.A.4, due to differences, in this area, in the breakdown of basic energy statistics. Such emissions are included instead in transport emissions (1.A.3).

While emissions from agricultural transports and from mobile residential sources are reported within source category 1.A.4, the relevant emissions data is obtained together with data for the transport sector. This section does not include a description of the method in which these emissions are calculated.

The following Figure 25 shows relevant allocations within the Central System of Emissions.

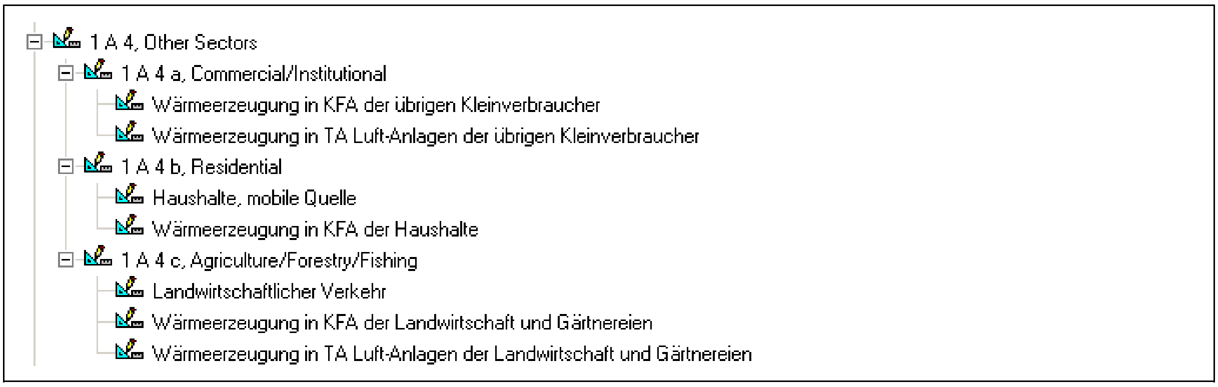


Figure 25: Structural allocation, 1.A.4 Other sectors

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 2000, more than 36 million combustion systems were installed in Germany in the Residential and Commercial/Institutional sectors (UBA, 2003d: p. 10). Combustion systems for solid fuels accounted for a majority of these systems, or some 14.6 million, while the group of gas-fired furnaces accounted for some 13.5 million systems and that of oil-fired furnaces accounted for some 7.9 million. The great majority of these systems (over 95 %) is in place in private households (UBA, 2000a and UBA, 2003d).

A part of the fuels used within this source category (primarily wood fuels) is not included in any official statistics. For this reason, the reliability of the reported data is limited. As in the approach used by the Working Group on Energy Balances (AGEB), use of waste and other biomass in the "Residential" sector is treated as equivalent to use of wood. For the same reason, use of waste and other biomass in the sector "Trade, commerce, services and other consumers" is treated as equivalent to use of sewage-treatment gas / biogas for energy recovery.

3.1.6.2 Methodological issues (1.A.4)

The **activity rates** in source category 1.A.4 are based on the Energy Balance for the Federal Republic of Germany, as prepared by the Working Group on Energy Balances. Lines 66 (residential) and 67 (commerce, trade, services and other consumers) (AGEB, 2003) are of primary importance.

Since the figures in Energy Balance line 67 (commerce, trade, services and other consumers) also include consumption by military agences, such consumption must be deducted from the relevant positions in line 67 (stationary sources within the military sector are described in source category 1.A.5.a, Chapter 3.1.7). For energy inputs in agricultural combustion systems, which are also included in line 67 of the Energy Balance, relevant data is available in an existing study (UBA, 2000a) for 1995. This study provides an estimate of agricultural combustion systems' share of total energy inputs in line 67. This share was assumed to be constant for the years until 2004.

The database for the **emission factors** used consists of UBA, 2000a. Within the context of this project, device-related and source-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 1995.

Determination of emission factors is based on a source-category-specific "bottom-up" approach that, in addition, to differentiating (sub-) source 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 source 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 corresponds to the Tier 2 method of the IPCC-GPG (2000: p. 2.92).

The emission factors are structured in accordance with the relevant fuels involved in final energy consumption in Germany:

- Fuel oil EL
- Fuel oil S/SA
- Natural gas
- Lignite (crude lignite, briquettes from the Rhine, Lausitz and central German regions, imported briquettes)
- Hard coal (coke, briquettes, anthracite) and
- Wood (natural wood, 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. In the commercial/institutional area, additionally, a distinction was made between installations not subject to licensing within the scope of validity of the 1st Ordinance on the Execution of the Federal Immission Control Act (*BImSchV*) (Ordinance on small and medium-sized combustion systems) and licensable installations that are subject to the requirements of the Technical Instructions in Air Quality Control (Clean Air Directive - *TA Luft*). 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. Supplementary to this, experiments were conducted on furnaces using solid fuels, both on the test bench and via measurements in the field.

The description of the plant structure for installed furnaces was prepared using statistics on residential and other buildings, statistics from the chimney-sweeping trade, and surveys by the researchers themselves in selected chimney-sweep districts of Baden-Wuerttemberg, North-Rhine Westphalia and Saxony. This data was used to estimate the energy inputs for various system types, to make it possible to determe sectoral emission factors weighted by energy inputs. Table 31 shows the sectoral emission factors determined.

Table 31: Sectoral emission factors for combustion systems in the residential, commercial and institutional areas

Residential	**CH_4 [kg/TJ]**	**N_2O [kg/TJ]**
Hard coal and hard-coal briquettes	273	11
Hard coal	259	12
Briquettes	293	10
Hard-coal coke	7,1	0,8
Lignite briquettes	105	4,4
Untreated wood	123	1,5
Heating oil EL	0,06	0,61
Natural gas	1,1	0,31
Commercial and institutional		
Hard coal and hard-coal briquettes	9,2	4,9
Hard coal	9,2	4,9
Briquettes	-	-
Hard-coal coke	20	0,81
Lignite briquettes	248	0,47
Untreated wood	96	0,99
Heating oil EL	0,02	0,56
Natural gas	0,12	0,34

On the basis of the emissions data calculated for the year 1995, the subsequent development of emission factors in 5-year stages up until the year 2020 was estimated using two scenarios.

3.1.6.3 Uncertainties and time-series consistency (1.A.4)

Calculating reliable emission factors in this plant sector is possible only via a complex procedure. Apart from emission figures, it is also necessary to obtain other information e.g. in order to make allowance for the relevant mode of operation (loads), plant 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 plants 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 plant types, moreover, only inadequate data or no data at all was available on emissions behaviour when using certain fuels. In this respect, it is important to bear in mind that for furnaces belonging to residential and commercial/institutional users, there is no statutory obligation to measure the greenhouse gas emissions under consideration. When calculating the emission factors, therefore, in most cases (with the exception of CO_2, which is largely independent from the furnace design) the researchers only had recourse to a few results from individual measurements on selected installations. In some of these cases, the data gaps were closed by adopting emission factors from comparable furnace designs or by using emission data from other studies.

The uncertainties listed for the emission factors for CH_4 and N_2O were determined via experts' assessment pursuant to IPCC-GPG (2000: Chapter 6). This assessment, which is based on the emissions data obtained for the aforementioned research project, was carried out by experts from the Federal Environmental Agency, in co-operation with the University of Stuttgart's Institute of Process Engineering and Power Plant Technology (Institut für Verfahrenstechnik und Dampfkesselwesen). The following sources of error entered into the estimate 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 plant data used (overall group structure in terms of type, age and performance and fuel consumption)

For all of these influencing factors, it proved useful to differentiate between systems burning liquid and gaseous fuels and systems burning solid fuels. All uncertainties, with the exception of the measuring error in N_2O measurement, must be considered greater for systems burning solid fuels than for systems burning liquid or gaseous fuels. One reason for this is that the group of solid fuels comprises many different fuels, with different emissions behaviours (e.g. various types of lignite, hard coal and wood, from various different origins and with various different characteristics); in systems burning gaseous or liquid fuels, on the other hand, almost all emissions result from use of natural gas or light heating oil.

In gas-fired systems in particular, another error occurs in determination of start/stop emissions. During start-up/shutdown procedures, some partly unburned CH_4 is emitted from natural gas. These emissions, which occur upstream and downstream from the actual combustion process, cf. Chapter 3.2.2.2 (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, in a first approximation, a normal distribution is assumed for N_2O emission factors. Given the considerably larger uncertainties for CH_4 (up to 100%), on the other hand, it must be assumed that deviations toward larger values in this area are considerably more pronounced than those toward smaller values. For this reason, a log-normal distribution must be assumed for CH_4, for all fuels.

In the aforementioned research project, the emission factors for CH_4 and N_2O were determined in five-year steps for the period 1995 (reference year) through 2020. With this approach, no changes result for most of these emission factors for the period until 2003. The CH_4 emission factors were forecast to decrease slightly only in the area of use of some solid fuels (lignite, wood). This is due primarily to modernisation of existing systems (replacement of old systems with new systems with lower emissions) and, in part, to changes in fuel-consumption structures (sharply decreasing use of eastern German lignite since 1990). In a good approximation, constant emission factors for this period may be assumed for N_2O, which is largely fuel-dependent in small combustion systems.

For the period 1990 to 1994, source-specific recalculation of emission factors was carried out; as a rule, this process was able to draw on existing emission factors from 1995 (cf. 3.1.6.5).

Annex 2, Chapter 13.7 describes the method used to determine the uncertainties for the **activity rates**.

3.1.6.4 Source-specific quality assurance / control and verification (1.A.4)

For the purposes of quality assurance, 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 was examined with a view to validity. The review included comparisons with confirmed data and plausibility checks. As a general principle, in description of the emissions behaviour of combustion systems, emissions data was 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. Records were kept, by the research company, of all key materials used for inventory preparation.

In a quality review carried out by Federal Environmental Agency experts, pursuant to IPCC-GPG (2000: Chapter 2.2.3 and 8), the country-specific emission factors for CH_4 and N_2O, as determined pursuant to Tier 2, were compared with the IPCC Tier 1 default factors of the IPCC Reference Manual (1996b). For most fuels, the values agreed well (discrepancies within one order of magnitude), although the default values for CH_4 tended to be higher, and those for N_2O lower, than the country-specific values. Larger discrepancies occurred only for fuel oil; they are due to the very high Tier 1 default value (10 kg/TJ CH_4 for "oil"). A comparison with the relevant Tier 2 default value (0.7 kg/TJ CH_4 for "distillate fuel oil") produces considerably smaller discrepancies from the country-specific values.

Furthermore, data was compared with that for Austria, whose plant and fuel-consumption structures are similar to those of Germany (UBA Wien, 2004, 2004). The results included good agreement of emission factors, with lower discrepancies overall than seen in the default-value comparison.

3.1.6.5 Source-specific recalculations (1.A.4)

The emission factors are consistent throughout the time series for the period 1990 to 2003. Necessary recalculations were already carried out in 2004 and described in the NIR 2005.

Initially, the emission factors for the years 1990 to 1994 diverged considerably from the factors used as of 1995, and they were inadequately substantiated. UBA 2000a contains valid data, broken down by the old and new German Länder, for the year 1995. Since the emission factors for the greenhouse gases CH_4 and N_2O change only slightly over periods of several years, this data was used for the years 1990 to 1994.

The activity rates for the period 1990 through 1994 have not yet been corrected. This applies only to the distribution of activity rates among sub- source categories in 1.A.4a and 1.A.4c, however. The procedure described above for the period 1995-2003 will provide the methodological starting point for such recalculation.

3.1.6.6 Planned improvements (source-specific) (1.A.4)

In order to create a broader database for calculating certain emission factors (particularly for CH_4 in connection with use of solid or gaseous fuels), further investigations are required. This is to be achieved within the context of research projects that have yet to be commissioned.

3.1.7 Other (1.A.5)

Source category 1.A.5 includes all combustion-related emissions that are not included in source categories 1.A.1 through 1.A.4. Most significantly, it includes the emissions of the military sector. Although it is divided into the source categories 1.A.5a "*Stationary"* and 1.A.5b "*Mobile"*, the data for this category is reported in combined form.

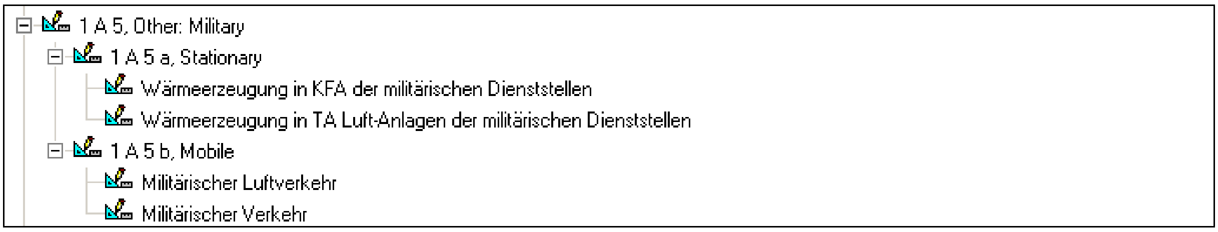


Figure 26: Structural allocation, 1.A.5 Other

3.1.7.1 Source-category description (1.A.5)

CRF 1.A.5					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
All Fuels	l / t	CO_2	0,93 %	0,16 %	falling

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**NMVOC**	**VOC**	**SO_2**
Emission factor (EF)	NO	CS	NO	NO	NO	NO	NO	NO	NO	NO
EF uncertainties in %		25								
Distribution of uncertainties		N								
Method of EF determination		CS								

Source category 1.A.5 is a key category for CO_2, for solid and liquid fuels, in terms of trend.

3.1.7.2 Methodological issues (1.A.5)

The Energy Balance of the Federal Republic of Germany (AGEB 2004) provides the basis for the **activity rates** used. Since the Energy Balance does not provide separate listings of military agencies' final energy consumption as of 1995 – and includes this consumption in line 67, under "commerce, trade, services and other consumers" – additional sources of energy statistics had to be found for source category 1.A.5.

For source category 1.A.5a, use was made of data of the Federal Ministry of Defence (BMVg, 2004), which has reported the "Energy input for heat generation in the German Federal Armed Forces", by fuels and for 1995-2004, to the Federal Environmental Agency. These figures were deducted from the figures in Energy Balance line 67 (commerce, trade, services) and are reported in 1.A.5, rather than in 1.A.4.

For source category 1.A.5b, military fuel and aircraft-fuel consumption for 1995-1999, in TJ, was drawn from a special analysis of the Working Group on Energy Balances (AGEB). The following source was used for the years 2000-2004: Association of the German Petroleum Industry (Verband der Mineralölwirtschaft; MWV; 2005), Mineralöl-Zahlen 2004, p. 32. The consumption figures, which are given in units of 1000 t, were converted into TJ on the basis of the relevant heating statistics listed for 2002.

The database for the **emission factors** used for source category 1.A.5a consists of UBA (2000a). Within the context of this project, device-related and source-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 1995. The method used to determine the factors conforms to the procedure described for source category 1.A.4. Table 32 shows the sectoral emission factors used.

Table 32: Sectoral emission factors for combustion systems of military agencies

Military	CH_4 [kg/TJ]	N_2O [kg/TJ]
Hard coal and hard-coal briquettes	2,4	4,8
Hard-coal coke	19	0,8
Lignite briquettes	242	0,37
Crude lignite	368	
Heating oil EL	0,02	0,56
Natural gas	0,02	0,29

3.1.7.3 Uncertainties and time-series consistency (1.A.5)

Information regarding the uncertainties for the emission factors is provided in the description for source category 1.A.4. Annex 2 Chapter 13.7 describes how the uncertainties for the activity rates were determined.

3.1.7.4 Source-specific recalculations (1.A.5)

Information regarding the source-specific recalculations is also provided in the description for source category 1.A.4.

3.1.8 Comparison with the CO_2 reference procedure

Reporting on combustion-induced CO_2 emissions is centrally important within the context of international climate protection. To this end, industrialised countries routinely adopt the source-category-specific approach, which addresses the level of individual energy consumption sectors and therefore permits differentiated statements on the structure of emitters. By way of a comparative approach, the *Intergovernmental Panel on Climate Change* (IPCC) has developed the *Reference Approach*, which is based on the level of primary energy consumption (input of energy resources in a given country). This approach places less demanding requirements on the databases than does the source-category-specific approach.

The Reference Approach was carried out for all years in question. This entailed a problem in that publication of the detailed Energy Balance editions required for the work is subject to time lags of several years. Currently, balances up to the year 2002 are available. To permit use of the Approach nonetheless, as required, for all years covered by the report, the Wuppertal Institute developed a procedure, in the framework of a research project, that is based on the evaluation tables, publication of which is subject to smaller time lags. The results of the project are presented in the Annex, Chapter 13.9.

The results of the Reference Approach are compiled in Table 33. In Figures 31 and 32, they are compared with the various relevant data records. In an average for all years in question, the discrepancy between the results obtained with the Reference Approach and those obtained with the sectoral calculation approach is 0.4 %. The discrepancies vary throughout a range of – 2.2 to + 1.1 %.

PROGNOS AG has carried out a research project for analysing the Reference-Approach calculation procedure (PROGNOS, 2000). The main results of the project are presented in the Annex, Chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**.

3.1.9 Emissions from international transports (1.BU.1/1.BU.2)

The area of international transports is divided into international civil air transports (1.BU.1) and international sea transports (1.BU.2), the latter of which also includes blue-water fisheries and marine navigation.

3.1.9.1 Emissions from international air transports (1.BU.1)

Emissions from fuel consumption for international air transports are included in inventory calculation; however, in agreement with IPCC Good Practice Guidance (IPCC, 2000: p. 2.57) they are not reported as part of national total inventories.

German energy statistics do not yet provide an official breakdown of fuel consumption relative to international air-traffic emissions. To make it possible to differentiate national and international consumption nevertheless, these fuel-consumption statistics are broken down into shares of 20 % for domestic air transports and 80 % for international air transports. This relation was confirmed via a research project for the year 1996. Overall, this estimate must be considered very conservative, since it breaks down the strong growth in air transports into consistent shares for national and international air transports. In actual practice, this strong growth, over the last 12 years, has most likely taken place very predominantly in the international air transports sector.

Currently, R&D activities are being prepared for a joint project of the European Community (European Commission, EUROSTAT, EUROCONTRL and EEA) for calculation of emissions, from national and international air transports, for the levels of the individual Member States and the entire European Union. This project is expected to be able to solve the aforementioned problems.

International civil aviation is separately listed as such in the CSE.

Figure 27: Structural allocation, 1.BU.1 civil air transports (international)

3.1.9.2 Emissions from international sea transports / transport navigation (1.BU.2)

CRF 1.BU.2: TABLE 1.C sectoral background data for energy					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
Transport Navigation					
	- / -				

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	CS	D	--	--	--	D	D	D	D	D
EF uncertainties in %	--	10	--	--	--	10				
Distribution of uncertainties	--	--	--	--	--	--				
Method of EF determination	T1	T1	--	--	--	T1				

The source category international sea transports / transport navigation is not a key category.

International sea transports include international blue-water fisheries and marine transport, categories which are also listed as such in the CSE.

Figure 28: Structural allocation 1.BU.2 Navigation (international)

Emissions from fuel consumption for international transports of ocean-going ships are included in the inventory calculation although, in keeping with the UNFCCC guidelines, they are not reported as part of total national inventories.

In 1997, a total of 97,248 ships called at Germany's 19 ports on the North and Baltic seas. These ships spent a total of 902,057 hours in the sea areas of Germany's continental shelf, and they took on 715,537 tonnes of fuel, comprising heavy oil and marine diesel oil.

Consumption of heavy oil has been increasing since 1984 as a result of high petroleum prices, global increases in transports and increasing maritime use of diesel engines that can run on heavy oil.

The emissions fluctuations that occurred in the navigation sector in 1992 and 1996 were caused by trade and oil crises.

3.1.9.2.1 Methodological issues (1.BU.2)

The "Good Practice Guidance" (2000: page 2.52) specifies that, where good data is available, the Tier 2 method is to be used, along with country-specific CO_2 EF and engine-specific EF for CH_4 and N_2O. If no engine-specific energy consumption data is available, then the IPCC default emission factors for CH_4 and N_2O may be used. Where country-specific emission factors for CO_2 are lacking, calculations may be carried out on the basis of the IPCC default emission factors, as long as the source in question is not a key category.

For Germany, emissions from this source category as calculated as the product of consumed fuels and country-specific emission factors for CO_2 and default EF for CH_4 and N_2O. This procedure conforms to the Tier 1 method.

The activity rates for bunkerung are taken directly from the Energy Balance of the Federal Republic of Germany. The reason why these rates are is listed separately is that fuel purchased in ports is taxed differently. Current data from the Energy Balance of the Federal Republic of Germany is available for the period until 2001. For the period since then, statistics from the Association of the German Petroleum Industry (MWV; www.mwv.de) have been used.

For calculation of N_2O, CH_4, CO, NO_X and NMVOC emissions, default emission factors from the Revised 1996 IPCC Guidelines (Reference Manual, 1996b: p.1.90 Table 1-48) are used.

With regard to the CO_2 emission factor for diesel fuel, 74,000 kg/TJ, and to that for heavy heating oil, 78,000 kg/TJ, the reader's attention is called to the documentation in Annex 2, Chapter 13.8.

3.1.9.2.2 Uncertainties and time-series consistency (1.BU.2)

The responsible Federal Environmental Agency expert has estimated the uncertainties from the MARION model as amounting to 10%.

The MARION research project was carried out in 1995/1997. Its aim was to calculate the emissions balances for individual ships, for marine transports involving German ports.

The data entered into the project programme included all shipping routes, ship-specific consumption figures and a range of ship characteristics. The resulting transport terms and emissions terms were used to determine the total emissions for the various relevant ship types, as a function of size class. Oily residues of consumed heavy fuel oil, from operation of ships' main engines, were estimated as amounting to 2%. Ships' main engines were assumed to run at 85 %, and auxiliary engines were assumed to run at 30 %. It is not possible to carry out separate calculations for heavy oil and marine diesel oil.

3.1.9.2.3 Source-specific quality assurance / control and verification (1.BU.2)

Source-specific verification of the CO, CO_2 and NOx emission factors was carried out by comparing the country-specific emission factors, as used to that point, to the default emission factors. The verification was carried out in keeping with the MARION method.

3.1.9.2.4 Source-specific recalculations (1.BU.2)

Since availability of Energy Balance data was delayed, the activity rate for 2000 and 2001 was updated in the interest of better consistency. This had only minimal impacts, however.

3.1.10 Storage

Emissions from storage are not calculated at present. This data is only used within the context of the Reference Approach.

3.1.11 Military

Emissions from international deployments by the Federal Armed Forces, under a UN mandate, are currently not calculated as a separate activity for purposes of German emission inventories. However, this task is to be carried out soon within the framework of the National System.

This practice does not lead to any omissions in the inventories, since the fuel inputs associated with these actions are included in national military consumption figures.

The basis for activity data for military fuels consists of the official petroleum data for the Federal Republic of Germany (BAFA, 2003: Table 7j).

In the CSE, source category 1.A.5 includes, under stationary sources, heat production of military agences; under mobile sources, it includes military transports and aviation.

Figure 29: Structural allocation, 1.A.5 Other: Military

3.1.12 Quality assurance / control and verification (1.A)

Below, the results of the detailed source-category-based calculation of CO_2 emissions for Germany, carried out in accordance with the specifications of the *IPCC Good Practice Guidance* (2000), are compared with other national and international data on energy-related CO_2 emissions (data available to Germany), for verification purposes.

This is achieved by comparing the calculation results with data:

- from EUROSTAT
- from IEA (source-category-specific procedure and Reference Procedure)
- from the CO_2 calculations performed at *Länder* level.

Table 33 presents the results of the various CO_2 calculation approaches for comparison. For visualisation purposes, the data is also presented graphically, on a comparative basis over time, in Figure 30. This approach reveals the key development trends in all calculation approaches, including the Reference Approach, albeit at differing levels. In Figure 31, the relative deviations in the data records created by the varying calculations are depicted in order to illustrate these level differences.

Comparison of CO2 inventories with other independent national and international results for CO_2 emissions															
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Results / Deviations	**(Gg / Percent)**														
DIW (energiebedingte Emissionen)	**946,3**					**839,7**	**867,6**	**832,8**	**825,9**	**803,7**	**803,2**	**820,5**	**808,2**	**813,3**	**804,5**
Deviation DIW from UBA	0,1					0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	-0,1
EUROSTAT	**943,0**	**918,5**	**877,1**	**870,2**	**857,6**	**863,3**	**870,1**	**827,8**	**824,2**	**802,3**	**NE**	**NE**	**NE**	**NE**	**NE**
Deviation EUROSTAT from UBA	-0,3	0,3	0,6	0,8	1,5	2,8	0,3	-0,6	-0,2	-0,2	NE	NE	NE	NE	NE
IEA Statistics Sectoral Approach	**966,4**	**941,5**	**892,6**	**884,9**	**871,8**	**874,5**	**908,4**	**879,7**	**867,6**	**837,7**	**835,0**	**850,1**	**837,5**	**NE**	**NE**
Deviation IEA from UBA	2,1	2,7	2,4	2,4	3,1	4,0	4,5	5,3	4,8	4,1	3,8	3,5	3,5	NE	NE
IEA Statistics Reference Approach	**971,1**	**937,5**	**897,5**	**883,7**	**870,7**	**875,3**	**895,5**	**870,4**	**869,9**	**833,9**	**839,9**	**867,8**	**847,8**	**NE**	**NE**
Deviation IEA RA from UBA	2,6	2,3	2,9	2,3	3,0	4,1	3,2	4,3	5,0	3,6	4,4	5,4	4,7	NE	NE
Deviation IEA RA from UBA RA	-4,9	-4,7	-4,1	-4,6	-4,2	-2,3	-3,1	-2,5	-1,3	-1,5	-1,5	0,7	0,0	NE	NE
Results of the German Länder (energy)	**982,0**	**955,1**	**904,2**	**898,1**	**874,8**	**875,7**	**897,0**	**875,3**	**870,6**	**842,8**	**848,9**	**874,3**	**857,2**	**NE**	**NE**
Deviation German Länder from UBA	3,7	4,1	3,6	3,8	3,5	4,1	3,3	4,8	5,1	4,6	5,4	6,1	5,7	NE	NE
Reference Approach UBA	**1.018,6**	**981,2**	**934,7**	**924,4**	**907,0**	**895,7**	**923,0**	**892,4**	**881,1**	**846,6**	**852,1**	**861,8**	**848,2**	**859,5**	**849,0**
Deviation RA from UBA	1,1	0,7	0,9	0,9	0,7	-0,1	0,1	0,0	-0,4	-1,5	-1,4	-2,0	-2,2	-1,5	-1,9
Sectoral Approach UBA (1 A)	**945,7**	**916,0**	**871,5**	**863,6**	**844,4**	**839,5**	**867,1**	**832,9**	**826,0**	**803,7**	**803,4**	**820,7**	**808,2**	**813,6**	**805,2**

Table 33: Comparison of CO_2 inventories with other independent national and international results for CO_2 emissions

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2001	2002
	(Gg)														
1. Energy	**945.723,6**	**915.977,5**	**871.511,1**	**863.629,6**	**844.415,2**	**839.508,5**	**867.147,4**	**832.940,1**	**825.974,3**	**803.694,6**	**803.364,3**	**820.687,3**	**808.248,0**	**813.600,3**	**805.154,4**
A. Fuel Combustion (Sectoral Approach)	945.723,6	915.977,5	871.511,1	863.629,6	844.415,2	839.508,5	867.147,4	832.940,1	825.974,3	803.694,6	803.364,3	820.687,3	808.248,0	813.600,3	805.154,4
1. Energy Industries	413.994,0	401.798,9	380.180,3	370.452,4	366.380,8	356.637,0	361.849,7	344.068,6	346.784,9	333.809,0	347.487,9	353.232,9	360.611,1	367.122,9	363.824,1
2. Manufacturing Industries and Construction	153.104,4	134.188,6	124.004,3	113.519,8	112.538,3	111.833,4	110.098,0	107.651,8	103.036,2	104.455,3	100.502,1	98.677,9	95.004,2	96.116,0	99.479,7
3. Transport	162.486,5	166.043,5	171.711,5	176.586,9	172.956,1	176.676,9	176.776,5	177.276,0	180.546,3	186.189,8	182.430,0	178.430,6	176.346,6	170.338,3	171.185,9
4. Other Sectors	204.312,8	205.481,2	189.189,9	197.928,9	187.785,8	190.399,6	215.325,5	200.954,7	192.603,8	176.679,1	170.657,0	188.479,6	174.380,3	178.090,4	169.008,5
5. Other	11.826,0	8.465,4	6.425,1	5.141,6	4.754,2	3.961,7	3.097,7	2.989,1	3.003,2	2.561,4	2.287,2	1.866,2	1.905,8	1.932,7	1.656,3
B. Fugitive Emissions from Fuels	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
1. Solid Fuels	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2. Oil and Natural Gas	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
2. Industrial Processes	**84.507,7**	**79.786,1**	**76.912,3**	**74.815,1**	**79.993,6**	**80.646,4**	**76.460,6**	**81.760,0**	**80.697,6**	**77.990,4**	**82.893,9**	**78.613,7**	**78.232,3**	**78.944,9**	**80.699,8**
A. Mineral Products	22.973,1	20.987,3	21.780,7	22.024,1	23.432,0	23.169,4	21.941,2	22.503,0	22.509,0	22.733,0	22.347,2	20.208,3	19.395,2	20.073,6	20.614,3
B. Chemical Industry	11.822,7	11.280,4	11.270,4	11.323,9	11.893,1	12.661,8	13.007,8	12.793,2	13.221,9	13.256,2	14.153,2	13.910,0	14.199,6	14.738,9	14.878,5
C. Metal Production	49.711,9	47.518,3	43.861,2	41.467,0	44.668,4	44.815,2	41.511,6	46.463,8	44.966,7	42.001,2	46.393,6	44.495,4	44.637,5	44.132,4	45.207,0
D. Other Production	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
E. Production of Halocarbons and SF_6															
F. Consumption of Halocarbons and SF_6															
G. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3. Solvent and Other Product Use	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
4. Agriculture	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**
A. Enteric Fermentation	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
B. Manure Management	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
C. Rice Cultivation	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
D. Agricultural Soils (2)	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
E. Prescribed Burning of Savannas	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
F. Field Burning of Agricultural Residues	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
G. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Table 33 (con'd): Comparison of CO_2 inventories with other independent national and international results for CO_2 emissions

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2001	2002
	(Gg)														
5. Land-Use Change and Forestry [3]	**-28.615,7**	**-29.472,2**	**-30.150,4**	**-30.632,7**	**-31.277,0**	**-31.536,7**	**-31.968,1**	**-32.368,8**	**-32.626,9**	**-33.088,0**	**-34.354,3**	**-35.127,7**	**-35.349,0**	**-35.870,2**	**-36.252,4**
A. Changes in Forest and Other Woody Biomass Stocks	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
B. Forest and Grassland Conversion	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
C. Abandonment of Managed Lands	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
D. CO_2 Emissions and Removals from Soil	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
E. Other	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
6. Waste	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
A. Solid Waste Disposal on Land	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
B. Waste-water Handling															
C. Waste Incineration	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
D. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
7. Other *(please specify)*	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Total Emissions/Removals with LUCF [4]	**1.001.615,6**	**966.291,4**	**918.273,0**	**907.811,9**	**893.131,8**	**888.618,2**	**911.639,9**	**882.331,3**	**874.045,1**	**848.597,0**	**851.904,0**	**864.173,3**	**851.131,3**	**856.674,9**	**849.601,8**
Total Emissions without LUCF[4]	**1.030.231,3**	**995.763,6**	**948.423,4**	**938.444,6**	**924.408,8**	**920.154,9**	**943.608,0**	**914.700,1**	**906.672,0**	**881.685,0**	**886.258,2**	**899.301,0**	**886.480,3**	**892.545,2**	**885.854,2**
Memo Items:															
International Bunkers	**19.569,2**	**18.101,4**	**17.818,2**	**19.917,2**	**19.874,7**	**20.420,4**	**21.008,8**	**22.018,2**	**22.088,4**	**23.341,7**	**24.509,7**	**24.140,2**	**24.483,7**	**25.525,7**	**26.213,8**
Aviation	11.589,4	11.366,7	12.200,2	12.891,8	13.398,4	13.887,1	14.536,9	15.096,7	15.523,1	16.656,2	17.488,5	17.042,4	16.891,2	17.150,8	17.632,1
Marine	7.979,8	6.734,7	5.618,1	7.025,5	6.476,3	6.533,3	6.471,8	6.921,6	6.565,3	6.685,5	7.021,2	7.097,8	7.592,6	8.375,0	8.581,7
Multilateral Operations	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**7.564,3**	**7.111,4**	**7.264,6**	**7.303,4**	**7.251,5**	**7.033,4**	**6.789,2**	**7.797,9**	**8.056,6**	**9.257,2**	**10.350,1**	**11.097,5**	**11.586,3**	**12.196,5**	**12.765,4**

(1) IEA OECD Statistics "CO2 Emissions from fuel combustion 1971 - 2002" Edition 2004 (for 1990, 1995, 1998, 1999, 2000, 2001 2002), other figures from Edition 2002, Paris

(2) Länder Working Group on Energy Balances (AG Länderenergiebilanzen), Federal Environmental Agency analysis; also includes emissions from energy consumption for international transportsVerkehr

(3) Take the net emissions as reported in Summary 1.A of this common reporting format. Please note that for the purposes of reporting, the signs for uptake are always (-) and for emissions (+).

(4) The information in these rows is requested to facilitate comparison of data, since Parties differ in the way they report CO_2 emissions and removals from Land-Use Change and Forestry.

Table 33 (con'd): Comparison of CO_2 inventories with other independent national and international results for CO_2 emissions

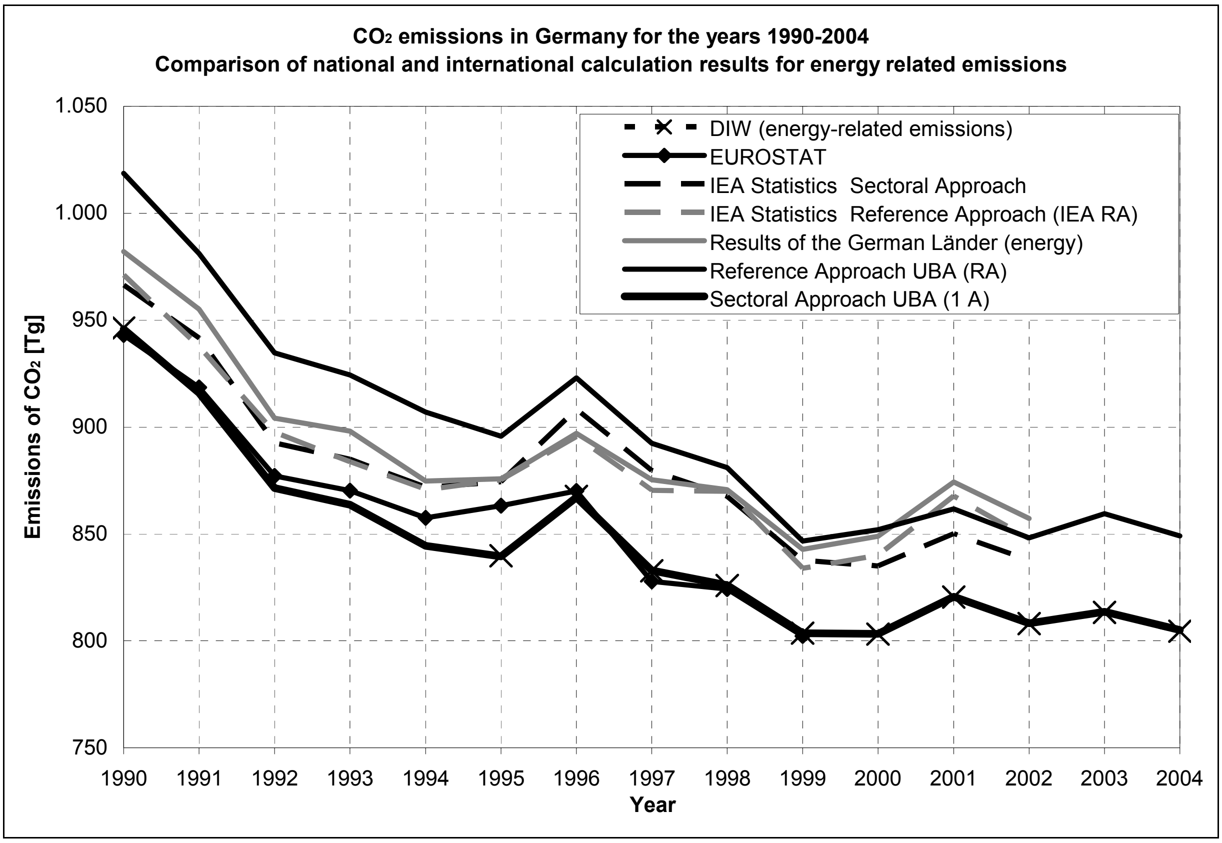


Figure 30: CO_2 emissions in Germany, 1990 - 2004 – Comparison of national and international calculation results

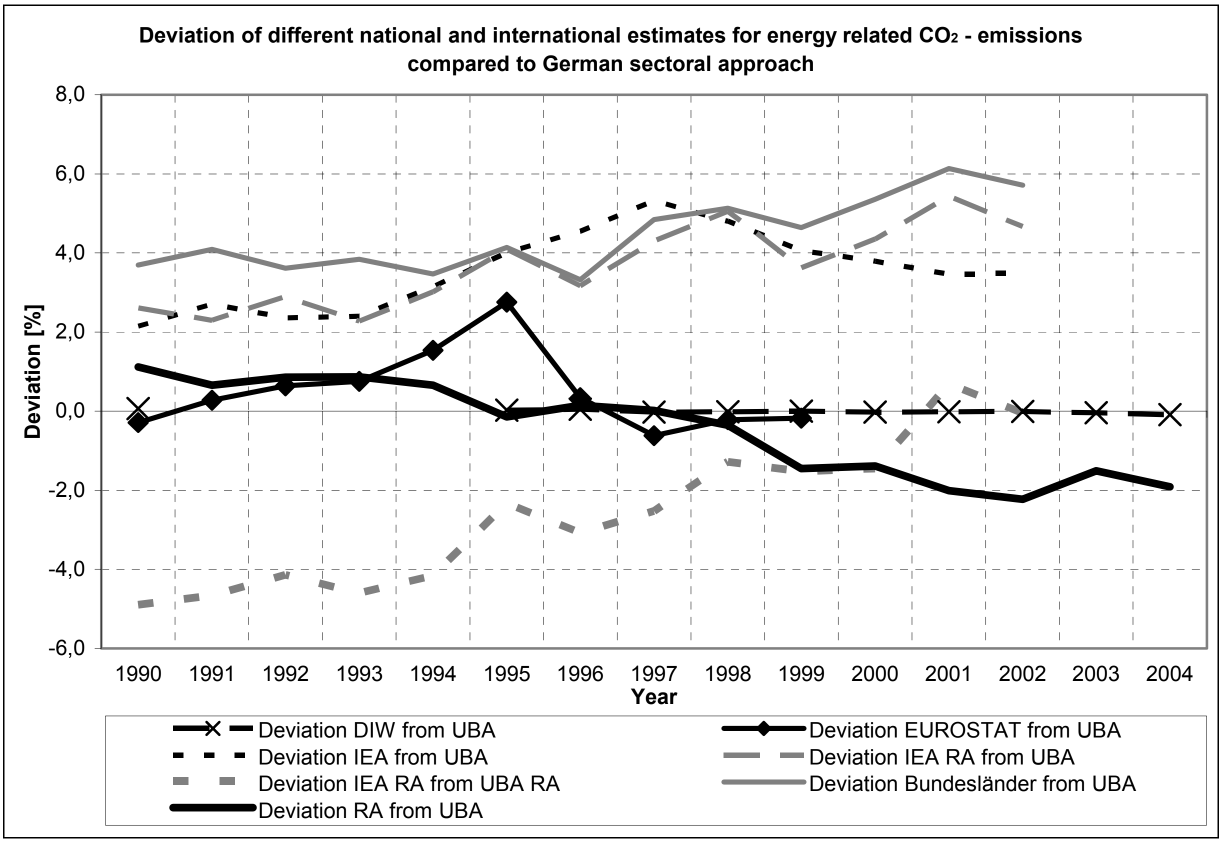


Figure 31: CO_2 emissions in Germany for the years 1990 to 2004 – Comparison of relative deviations of national and international calculation results

3.1.12.1 Comparison with the EUROSTAT results

The sectoral calculations carried out by EUROSTAT show good agreement with the results of sectoral calculations of energy-related emissions. The mean deviation for the years 1990 to 1999 is 0.5 %. The deviations vary throughout a range a range from – 0.6 % to + 2.8 %. With regard to comparisons from past years, reallocation of emissions of the iron and steel sector has resulted in better agreement with the results of EUROSTAT.

In 2001, the Federal Environmental Agency commissioned the German Institute for Economic Research (DIW), Berlin, and the Öko-Institut e.V. Institute for Applied Ecology, to carry out a research project for comparative analysis of national energy statistics and data of EUROSTAT. The project was co-financed by EUROSTAT. The results of the project (DIW, 2002) have since been published.

The reasons for the discrepancies in the calculation results need to be analysed, especially in light of the recent extensive changes made in emissions-calculation methods. For comparisons in the "old" structures, the reader is referred to last year's inventory report.

3.1.12.2 Comparison with the IEA results

Comparison with the IEA results was included here for reasons of completeness. Annually updated, internationally published data (most recently: OECD/IEA 2005) is available. The method of determining, processing and applying the basic data used for this purpose is not precisely comparable with the national procedure in Germany at present, due to a lack of the necessary further methodological information – particularly on the detailed data used.

However, results of the comparison confirm the data obtained via the national, detailed method (mean deviation over 13 years: 3.5 %; fluctuation between 2.1 and 5.3 %).

While the results of the Reference Approach carried out by IEA diverge relatively extensively (- 4.9 %) from those of the Reference Approach carried out in Germany for 1990, the two sets of Reference Approach results have been moving continuously into better agreement (and were nearly identical for 2002).

The reasons for the discrepancies between the results of the two calculation approaches need to be analysed, especially in light of the recent extensive changes made in emissions-calculation methods. For comparisons in the "old" structures, the reader is referred to last year's inventory report.

3.1.12.3 Comparison with the data obtained for the individual Federal *Länder*

Cooperation between the competent authorities and institutions of Germany's Länder takes place in the framework of the Länder Working Group on Energy Balances (Länderarbeitskreis Energiebilanzen). This group includes representatives of the Ministries of the Länder responsible for the energy industry – these are generally the industry or environment ministries – as well as the energy officers of the Statistical Offices of the Länder where these are appointed to prepare the energy balance for the respective *Land*. The Working Group also includes representatives of economic institutions which prepare the energy balance, under commission, in selected Länder.

The principle task of this Länder Working Group is to co-ordinate the preparation of energy balances for the various Länder. Since the balance year 1995, these balances have been prepared according to a uniform agreed and binding method[17].

In 1998, the Länder Working Group on Energy Balances also adopted the preparation of CO_2 balances for the Länder as one of its duties. Since then, it has published CO_2 balances for a growing number of Länder; these balances are likewise prepared on the basis of the energy balances for the Länder, according to standardised rules. Two different approaches are adopted:

Source balance – this refers to an account of emissions based on the primary energy consumption of a *Land*, subdivided according to emission sources, transformation sector and final energy consumption. The source balance allows statements to be made regarding the total volume of carbon dioxide emitted in a *Land* as a result of the consumption of fossil fuels.

Consumption balance – this refers to an account of emissions based on the final energy consumption in a given *Land*. This approach also includes each *Land's* electricity and district-heat consumption and its "foreign trade balance" (from the viewpoint of the relevant *Land*) in the CO_2 balance. The reason for this parallel calculation method is that up to 70 % of energy consumption in individual Länder is based on the import of electricity and district heat from other Federal Länder. Only with this holistic approach is it possible to balance and evaluate the effects of prepared or implemented climate protection measures in the Federal Länder.

Since 2002, the Länder have also recalculated CO_2 emissions for the years since 1990. The following section presents a comparison of published Länder results (source balance) with inventories calculated at the Federal level for energy-related CO_2 emissions. The comparison, which focuses on the figures for the years 1990 through 2002, is hampered by the following constraints, however:

- Not all Federal Länder participate in the working group, which means that for a few Länder no comparable energy balance data can be used. Of those Länder who do participate in the working group, not all have prepared a CO_2 source balance to date.
- The available information is not always given in the form of consistent time series, so that not all the required data is available for all years; it thus became necessary to use appropriate techniques to close the gaps. For Länder with published data, these are based on interpolation or extrapolation. For Länder with no published information, the procedures normally involve evaluation of statistics for primary and final energy consumption (percentage changes and correlation with the relevant population figures) as well as use of analogies for transferring pertinent coefficients between Länder.

The following section presents a compilation, for the years 1990 through 2002, of the data and results used. For reasons tied to the manner in which the data was obtained, as explained above, the data and results should be seen only as an orientation.

[17] Information about the methods developed and used in the working group can be found on the Internet at http://www.lak-energiebilanzen.de. The data available from that site in March 2003 was used for the purposes of this comparison.

Table 34: Comparison of the results of the CO_2 calculations of individual Länder with the national inventories for the years 1990 to 2002[18]

Land (State)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Baden-Württemberg	74,4	78,6	78,0	78,7	74,5	78,1	81,8	78,6	80,1	77,4	74,9	80,1	76,5
Bavaria	69,0	72,9	72,7	76,0	74,2	74,8	78,3	76,8	77,7	76,5	75,0	76,7	73,6
Berlin	26,9	28,0	25,2	26,6	25,5	24,4	24,7	23,9	23,5	23,5	23,5	23,9	21,1
Brandenburg	81,9	66,8	58,9	57,1	54,0	50,8	50,3	50,8	59,3	58,8	60,6	61,0	61,5
Bremen	13,4	13,6	12,9	12,5	13,3	13,2	14,2	14,1	13,8	12,8	14,1	14,1	14,0
Hamburg	12,7	14,2	13,1	13,8	13,4	13,5	14,6	13,9	***13,7***	***13,7***	***13,8***	***13,9***	***13,9***
Hesse	50,3	53,9	53,3	56,1	56,2	56,1	59,9	57,3	57,2	54,7	56,1	57,9	55,0
Mecklenburg - West Pomerania	***35,6***	***24,9***	***17,8***	***14,3***	***12,5***	11,0	12,3	11,2	10,9	10,6	10,3	10,7	10,9
Lower Saxony	79,5	84,8	***83,4***	***82,0***	80,6	***80,4***	80,3	***81,3***	82,4	***79,4***	76,3	***75,2***	74,1
North Rhine - Westphalia	298,9	309,7	304,7	299,9	295,4	303,1	311,0	305,7	304,7	291,5	293,9	298,4	294,1
Rhineland-Palatinate	***24,9***	***26,4***	***26,4***	***27,7***	***27,1***	***27,3***	***28,6***	***28,1***	***28,5***	***27,9***	***27,2***	***27,7***	28,0
Saarland	***21,1***	***21,4***	***20,4***	***19,8***	***21,3***	***21,1***	***22,8***	***22,7***	***22,2***	***20,7***	***22,8***	24,0	23,7
Saxony	91,5	77,1	64,1	66,0	63,0	61,3	56,2	51,0	37,2	35,1	41,6	48,8	49,0
Saxony-Anhalt	50,9	38,1	31,9	27,9	26,3	25,2	25,7	25,3	25,3	26,9	26,3	26,8	27,5
Schleswig-Holstein	22,8	22,5	22,8	23,4	23,4	22,0	22,5	21,7	21,4	20,9	20,4	22,6	***22,1***
Thuringia	28,1	22,1	18,7	16,3	14,0	13,3	13,7	12,8	12,7	12,4	12,1	12,4	12,1
Total for all German Länder	**982,0**	**955,1**	**904,2**	**898,1**	**874,8**	**875,7**	**897,0**	**875,3**	**870,6**	**842,8**	**848,9**	**874,3**	**857,2**
National result (CRF 1A)	**945,7**	**916,0**	**871,5**	**863,6**	**844,4**	**839,5**	**867,1**	**832,9**	**826,0**	**803,7**	**803,4**	**820,7**	**808,2**
Deviation [millions of tonnes of CO_2]	-36,3	-39,1	-32,6	-34,5	-30,4	-36,2	-29,8	-42,4	-44,7	-39,1	-45,5	-53,7	-49,0
Deviation [%]	-3,7	-4,1	-3,6	-3,8	-3,5	-4,1	-3,3	-4,8	-5,1	-4,6	-5,4	-6,1	-5,7

In terms of trend, the comparison found excellent agreement between the combined Länder results and the Federal inventory. On an average for the 13 years in question, the total CO_2 emissions for the Länder were about 4.5 % higher than the Federal result. The deviations ranged from -3.4 % in 1996 to -6.5 % in 2001. On the whole, these comparisons confirm the CO_2-emissions figures obtained for Germany as a whole.

3.1.12.3.1 Planned improvements

The calculation method chosen was revised this year. Following the reporting process, the results will discussed, regularly and intensively, with the representatives of the Länder Working Group on Energy Balances (Länderarbeitskreis Energiebilanzen). On this basis, the method for comparison between the Länder result and the national result will be improved this year. This work will focus in particular on the methods chosen for closing the existing data gaps (decisions on analogies between the various Länder). Moreover, research will be undertaken to investigate the extent to which such comparisons can then be refined based on the consumption of individual energy resources or fuel categories. Yet another option for improvement is to improve provision of original Länder data to the Federal Environmental Agency, to reduce future needs for using the gap-closing procedure when data is lacking or when data is not provided on time.

The reasons for the discrepancies in the calculation results need to be analysed, especially in light of the recent extensive changes made in emissions-calculation methods. This applies especially to the emissions reallocation carried out for the iron and steel sector. For comparisons within the "old" structures, the reader is referred to last year's inventory report.

[18] The figures in boldface italics are not part of consistent time series and were generated via gap-closure procedures (see text).

3.2 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 is the most important emission within the source category "solid fuels", fugitive emissions of oil and natural gas also include substantial amounts of carbon dioxide and nitrous oxide.

3.2.1 Solid fuels (1.B.1)

The source category "Solid fuels" (1.B.1) consists of three sub- source categories – the source category "Coal mining" (1.B.1.a), the source category "Coal transformation" (1.B.1.b) and the source category "Other" (1.B.1.c).

Table 35 presents the scheme for source category allocation and the relevant calculation methods (Table 36).

Table 35: Allocation of methane emissions to areas of the CRF

Source category			**Included emissions**
1.B.1.a. Coal mining and handling			
	i.	**Underground Mines**	
		Mining activities	Emissions from active underground hard-coal mining. The total emissions from pit gas flows and pit-gas removal are reduced by the amount of pit gas used.
		Post-mining activities	Emissions from processing, storage and transport of hard coal
	ii.	**Surface mines**	
		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.
		Post-mining activities	No separate listing – the emissions are already included in "mining activities"
1.B.1.b. Solid fuel transformation			Emissions from coal processing. This area takes account of specific emissions that occur in hard-coal processing (hard-coal coke, hard-coal briquettes). Emissions from lignite processing (lignite coke, coal dust, dry coal, fluidised-bed coal, lignite briquettes, lignite granulate) are already included in 1.B.1.a.ii "Mining activities". The assumed activity rate covers the total for all processed products from hard coal and lignite.
1.B.1.c. Others			
		Abandoned mines	Methane emissions for decommissioned hard-coal mines are listed here. No methane emissions from decommissioned lignite mines are recorded. Specification of an activity rate is not required.

In keeping with allocation of emissions to the various areas of the CRF table for "1.B.1 – Fugitive emissions from solid fuels", the following table presents calculated values for 2004 activity data, along with information regarding the origin of the data.

Table 36: Calculation of methane emissions from coal mining for 2004

			Activity data [Mt]	CH_4 emissions [Gg]
1.B.1.a. Coal mining and handling			**204,96** (= 1.B.1.a.i + 1.B.1.a.ii)	(= 1.B.1.a.i + 1.B.1.a.ii) = 305,65+2,00 **= 307,65**
	i.	**Underground mines**	**25,88** Hard-coal production 1)	= mining + post-mining = 290,74 + 14,91 **= 305,65**
		Mining activities		= AR * EF = 25,88 *11,23 **= 290,74**
		Post-mining activities		**= 14,91**
	ii.	**Surface mines**	**181,92** Lignite mining 1)	= Mining activities **= 2,00**
		Mining activities		= AR * EF = 181,92 * 0,011 **= 2,00**
		Post-mining activities		(included in 1.B.1.a.ii) **IE**
1.B.1.b. Solid fuel transformation			**13,82** Total for processed products 2) 1)	$AR_{H\text{-coal production}} * EF_{H\text{-coal production}} + AR_{lignite production} * EF_{lignite production}$ = 8,46 * 0,049 + 5,36 * 0 **= 0,41**
1.B.1.c. Others				= Abandoned mines **= 70,91**
		Abandoned mines	**NO**	Potential emissions, minus gas usage **= 70,91**

1) pursuant to STATISTIK DER KOHLENWIRTSCHAFT (2005b)
2) Hard-coal coke, hard-coal briquettes, lignite coke, coal dust, dry coal, fluidised-bed coal, lignite briquettes, lignite granulate

3.2.1.1 Coal mining and handling (1.B.1.a)

3.2.1.1.1 General description of the source category Coal mining and handling (1.B.1.a)

CRF 1.B.1.a					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
Solid Fuels	l / t	CH_4	1,45 %	0,61 %	falling

Gas	CO_2	CH_4	HFC	PFC	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)	NO	CS	NO	NO	NO	NO	NO	NO	NO	NO
EF uncertainties in %		-								
Distribution of uncertainties		-								
Method of EF determination		T2								

In Germany, fugitive methane emissions from coal mines are a key category category, in terms of both emissions levels and emissions trend.

For the source category Coal mining and handling (1.B.1.a), the only truly significant emissions tend to be those from ongoing extraction (coal-seam methane, CSM). Emissions from hard-coal processing are listed in source category 1.B.1.b, while emissions from decomissioned hard-coal mines (coal-mine methane, CMM) are listed in source category 1.B.1.c. This breakdown applies only to hard coal. For lignite, the chosen calculation procedure places all emissions in 1.B.1.a(.ii).

During coal production, transport and storage, methane can escape from coal and the rock surrounding it. The amount of methane released depends primarily on the amount of methane stored in the coal. All of the emissions that result from this relationship – but not the greenhouse gases caused by coal combustion – are to be recorded in this source category.

In the mining sector, a distinction is made between open-pit mines, in which raw materials are extracted from pits open to the surface, and closed-pit mines, in which seams are mined underground. In Germany, hard coal is mined in 3 coal fields (Reviere), in a total of 10 mines (all closed-pit), while lignite is mined in 6 coal fields, primarily with the open-pit method (14 pits; since 2003 all lignite mining is open-pit).

In underground coal mining, ventilation systems are used to keep mine methane concentrations within safe limits for mining. Such systems can emit significant amounts of methane into the atmosphere as they ventilate the air and gas mixtures prevailing in underground mines. Hard-coal mining is the principal source of fugitive emissions of CH_4. Some methane is suctioned off directly from seams and ancillary rocks and used, as pit gas.

Hard-coal production in 2004 amounted to some 26 million t of marketable production. Lignite production in 2004 totalled 182 million t (STATISTIK DER KOHLENWIRTSCHAFT, 2005b). As a result, hard-coal production increased by about 0.02 % over the previous year, while lignite production increased by about 1.6 %.

Methane emissions from hard-coal mines have decreased since 1990, as a result of decreasing production (while production increased slightly in 2004, the medium-term trend shows a clear decrease). Emissions from open-pit lignite mining have also decreased, also as a result of production decreases. On 10 November 2003, the Federal Government approved a financial framework for further support of the hard-coal sector, including support for further adaptation of production, from 26 million tonnes in 2005 to 16 million tonnes in 2012 (BMWA 2003). As a result, further decreases in methane emissions from hard-coal mining can be expected.

With regard to the international coal sector, an important aspect of lignite mining in Germany is that it has relied mainly on the open-pit method. What is more, since 2003 all lignite mining in Germany has been open-pit mining. One small underground lignite pit remained in operation until 2002. That pit was decommissioned in November 2002. Hard coal is mined only underground in Germany.

3.2.1.1.2 Methodological issues (1.B.1.a)

For calculation of CH_4 emissions from coal mining, emissions are determined for the areas of underground hard-coal mining, pit-gas use, hard-coal storage and open-pit lignite mining.

Emissions from hard-coal mining are calculated in keeping with the Tier 3 approach. 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 association of the German hard-coal mining industry (Gesamtverband des deutschen Steinkohlebergbaus) aggregates the individual measurements to determine total methane amounts. It then makes the resulting statistics available for the inventory (GVSt 2005a). Expert review is carried out by the competent state supervisory authority (the mining authority – Bergamt).

This approach meets requirements pertaining to mine-specific emissions determination pursuant to Tier 3. This approach thus replaces the Tier 2 approach used until the NIR 2005. The complete time series has been recalculated on the basis of the new data.

An emission factor (IEF) of 11.23 kg/t (2004) has been derived from the total methane emissions figures and from the relevant activity data for hard-coal mining. This calculation takes pit-gas usage into account. The measurements show only actually emitted methane amounts.

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. The emission factor of 0.576 kg/t has been taken from an FHG ISI study (1993).

Emissions from open-pit lignite mining have been calculated, in keeping with the Tier 2 approach, pursuant to the relevant equation in the IPCC Reference Manual (IPCC, 1996b).

The activity rate (crude lignite) has been taken from the STATISTIK DER KOHLENWIRTSCHAFT (2004a). According to 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. This emission factor is based on a 1989 study RWE Rheinbraun AG (DEBRIV, 2004) and is documented 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). This value is considerably lower than the previously used emission factor, 0.11 m³ CH_4/t, which was derived from the EF for American hard lignite. Such American EF cannot be applied to German soft lignite, since the latter's temperature did not exceed 50°C during the coal-formation process. Significant methane releases occur only at temperatures above 80°C, however.

No lignite storage takes place; usage is "mine-mouth", i.e. extracted coal is moved directly to processing and to power stations.

3.2.1.1.3 Uncertainties and time-series consistency (1.B.1.a)

The uncertainties in the activity rate 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 methane 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 %.

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 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).

Apart from the emission factor for pit-gas release from underground hard-coal mining, the emission factors are consistent in the time series, within the meaning of comparability throughout the time series. For the activity rates, a consistent source is used throughout the entire time series.

3.2.1.1.4 Source-specific quality assurance / control and verification (1.B.1.a)

For underground hard-coal mining, the IPCC Reference Manual (1996b) recommends 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/$10^6 m^3$ (pursuant to IPCC Reference Manual, 1996b: at 20° C, 1 atmosphere) yields the individual values listed in Table 37. When production, storage and deductable pit-gas use are combined in one emission factor, the resulting value per tonne of coal (marketable production) lies within the recommended range.

Table 37: Emission factors for CH_4 from coal mining, for 2004

Emission factors	**Hard coal**		**Lignite**	
	EF m^3 CH_4/t	**EF kg/t**	**EF m^3 CH_4/t**	**EF kg/t**
CH_4 from extraction	26,70	17,89	0,016	0,011
CH_4 from extraction, minus pit gas used	16,76	11,23	-	-
CH_4 from storage	0,86	0,58	-	-
CH_4 from mining (extraction and storage, minus pit-gas use)	17,62	11,81	0,016	0,011

The IPCC Reference Manual (1996b) does not recommend any specific emission-factor levels for open-pit lignite mining.

For reporting, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents.

In the framework of verification, various data sources for activity rates in coal mining, and the relevant EF used, were compared with the corresponding sources and EF of other countries.

A by-country comparison of specific emission factors for underground coal mining shows a broad range, with Germany in the lower part of the range, in a position comparable to that of the Czech Republic. France's EF lies considerably higher within the range, while Poland's is considerably lower. Both of these countries' EF lie outside of the UNFCCC's default values.

A by-country comparison of specific emission factors for open-pit coal mining shows that Poland, France (where production was discontinued in 2002) and Germany have relatively low emission factors that are below the default values. The reason for this is that the relevant coal in these countries has very low methane content, as a result of its degree of coalification and its geological history. Consequently, suitably low emission factors have to be applied to it. The comparison value for the Czech Republic is considerably higher, since its coal is not the "lignite" found in Germany, which has a low degree of coalification; instead, its coal is largely "sub-bituminous coal", which has a higher degree of coalification and higher methane content.

3.2.1.1.5 Source-specific recalculations (1.B.1.a)

Recalculations were carried out in order to improve the consistency of the method and to make corrections on the basis of results of inventory reviews.

The recalculations, made using the substitution method, were carried out for all time series, for the 1990 through 2004 period, and for the territory of Germany. Divergences of regional reference exist for fugitive lignite emissions for the 1990 through 1995 period, with the territorial references "old German Länder" and "new German Länder".

The activity rates were oriented to a better, transparent source. The emission factors were improved on the basis of results of inventory reviews.

The changes in the method, in the emission factor and in the activity rate are shown in the recalculation table (cf. the inventory, Table 8b).

3.2.1.1.6 Planned improvements (source-specific) (1.B.1.a)

Review will be carried out to determine what available data can be used in future as a basis for determining CO_2 and N_2O emissions (and, where data is available, also as a basis for determining emissions of CO, SO_2, and higher hydrocarbons). All improvements will include consideration of the uncertainties in emission factors.

The comparison of calculation procedures and results from source category 1.A, procedures and results for which BEU data is used, is being applied to improving accuracy, ruling out double counting and enhancing transparency.

3.2.1.2 Solid fuel transformation (1.B.1.b)

3.2.1.2.1 Source-category description (1.B.1.b)

CRF 1.B.1.b					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
	- / -				

Gas	CO_2	CH_4	HFC	PFC	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)	NO	CS	NO	NO	NO	NO	NO	CS	CS	CS
EF uncertainties in %										
Distribution of uncertainties										
Method of EF determination		CS								

Emissions from hard-coal-coke production play an especially significant role in this sub-source category.

3.2.1.2.2 Methodological issues (1.B.1.b)

The IPCC Reference Manual does not describe any methods for this source category (IPCC 1996b, p.1.110f). The country-specific method that is used is based on activity rates from the STATISTIK DER KOHLENWIRTSCHAFT (2004) and on corresponding emission factors.

Production of low-temperature lignite coke took place solely in the new German Länder and, for purposes of the inventory, is of relevance only to the base year. Production was discontinued after 1992.

3.2.1.2.3 Calculation procedure (1.B.1.b)

Emissions from hard-coal-coke production have been calculated pursuant to the Tier 2 approach, in a manner similar to that of the IPCC Reference Manual's equation for CH_4 emissions from coal mining:

Emissions [Gg CH_4] =

EF [m^3 CH_4 /t] * $AR_{processing\ product}$* conversion factor [Gg/$10^6 m^3$]

The activity rate for hard-coal-coke production has been taken from the STATISTIK DER KOHLENWIRTSCHAFT (2004a).

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 2005a). It is used for the entire time series.

In the CSE, the source category "coal transformation" is covered by the time series for hard-coal-coke production (coking plants).

No emissions are to be expected from processed lignite products, since the EF used for 1.B.1.a corresponds to the gas content of the lignite occurring in Germany.

3.2.1.2.4 Uncertainties and time-series consistency (1.B.1.b)

The uncertainties in the activity rate result primarily from measurement inaccuracies in weighing of produced coke. Via surveys of experts carried out during the NASE workshop of 11/2004, the relevant error has been quantified as <3 %.

As a result of technical changes in the relevant process, and of increasing use of exhaust-gas scrubbing, the emission factor used for calculation of methane emissions from hard-coal-coke production is subject to considerable uncertainty. According to experts, a factor of (20 % must be assumed (DMT 2005, along with information communicated personally at the NASE workshop 11/2004).

The emission factors remain at the same level in the time series and are thus consistent within the meaning of comparability throughout the time series. For the activity rates, a consistent source is used throughout the entire time series.

3.2.1.2.5 Quality assurance and verification (1.B.1.b)

For reporting, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents.

In consideration of emission factors, the IPCC conversion factor of 0.67 Gg/106m³ at 20°C and 1 atmosphere (IPCC et al; 1997, Reference Manual, p. 1.108) 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 Nm³ into m³.

Conversion factor, normal cubic metres (kilogrammes:

0.717 Nm^3/kg (1.01325 bar, 0°C) = **0.67 Gg/$10^6 m^3$** (20°C, 1 atmosphere) * **1.07 Nm³/m³**

3.2.1.2.6 Source-specific recalculations (1.B.1.b)

Recalculations were carried out in order to improve the consistency of the method and to make corrections on the basis of results of inventory reviews.

The recalculations, made using the substitution method, were carried out for all time series, for the 1990 through 2004 period, and for the territory of Germany. Divergences of regional reference exist for fugitive lignite emissions for the 1990 through 1995 period, with the territorial references "old German Länder" and "new German Länder".

The activity rates were oriented to a better, transparent source. The emission factors were improved on the basis of results of inventory reviews.

The changes in the method, in the emission factor and in the activity rate are shown in the recalculation table (cf. the inventory, Table 8b).

3.2.1.2.7 Planned improvements (source-specific) (1.B.1.b)

An effort can be made to refine the method from the Tier 2 level to the Tier 3 level, if the source category continues to be classified as a key category in future. Such refinement would require plant-specific determination of emission factors.

3.2.1.3 Other (1.B.1.c)

3.2.1.3.1 Source-category description (1.B.1.c)

CRF 1.B.1.c					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
	- / -				

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	NO	CS	NO	NO	NO	NO	NO	CS	CS	CS
EF uncertainties in %										
Distribution of uncertainties										
Method of EF determination		CS								

Emissions from decommissioned hard-coal mines play a significant role in this sub- source category.

As well as active mines, decommissioned hard coal mines (degassing) represent another relevant source of diffuse CH_4 emissions.

When a hard-coal mine is decommissioned, methane can escape from neighbouring rock, and from coal remaining in the mine, into the mine's network of shafts and passageways. Since the mine is no longer artificially ventilated, the methane collects and can then reach the surface via gas pathways in the overlying rock or via the mine's own shafts and passageways.

Such pit gas was long seen primarily as a source of danger (in active hard-coal mines) and as a negative environmental factor (in decommissioned hard-coal mines). Recently, increasing attention has been given to the gas' positive characteristics as a fuel (use for energy recovery). In the past, use of pit gas was rarely cost-effective (as shown by the example of the state of North Rhine – Westphalia). This situation changed fundamentally in 2000 with the Renewable Energy Sources Act (EEG). Although pit gas is a fossil fuel in finite supply, its use supports climate protection, and thus the gas was included in the EEG. The

Act requires network operators to accept, and provide specified compensation for, electricity generated with pit gas and fed into the grid. This framework has made it cost-effective to collect and use pit gas (BMWA, 2003b, p. 39). As a result, the $AR_{CMM\ collection}$ increased from 1.429 million m³ in 1998 to 45.527 million m³ in 2002 (figure from IVG (Interessenverband Grubengas) pit-gas interest association, provided via personal communication). Further increases are expected in the coming years.

In emissions reporting, amounts of pit gas used must be determined separately from released amounts of CH_4, must be broken down by active and decommissioned mines and must then be listed in source category 1.A. as energy production with relevant emissions (i.e. must be suitably offset).

3.2.1.3.2 Methodological issues (1.B.1.c)

The IPCC Reference Manual does not describe any methods for the sub- source category "Other" (IPCC et al, 1997, Reference Manual, p.1.110f).

As well as active mines and coal processing, decommissioned hard-coal mines (degassing) represent another relevant source of fugitive CH_4 emissions.

No emissions are to be expected from decommissioned open-pit lignite mines, since the EF used for 1.B.1.a corresponds to the gas content of the lignite occurring in Germany. Lignite that remains in decommissioned open-pit mines does not continue to release gas (DEBRIV).

This source category is subdivided into the following sub-areas:

- Underground mines, decommissioned hard-coal mines
- Decommissioned hard-coal mines, with pit-gas use

3.2.1.3.3 Uncertainties and time-series consistency (1.B.1.c)

It is quite practicable to determine the amounts of methane used; an uncertainty of < 3 % due to measurement inaccuracies is assumed. The total amounts of available methane in question have been estimated solely on the basis of experts' knowledge. In this area, an uncertainty of 50 % has been assumed.

The time series for potential methane emissions and amounts of methane used both originate from reliable sources and are consistent throughout.

3.2.1.3.4 Source-specific quality assurance / control and verification (1.B.1.c)

For reporting, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents.

In consideration of emission factors, the IPCC conversion factor of 0.67 Gg/10^6m³ at 20°C and 1 atmosphere (IPCC Reference Manual, 1996b, p. 1.108) should be applied to the units used in Germany: normal cubic metres at 1.01325 bar and 0°C (DIN 2004, DIN No. 1343). Users of emissions data published in Germany should assume that the relevant figures are in normal cubic metres. The IPCC Guideline figures are oriented to 20°C and 1,013 mbar. In keeping with methane's isobaric proportionality, the factor 1.07376 can be used to convert Nm³ into m³.

3.2.1.3.5 Source-specific recalculations (1.B.1.c)

Recalculation was carried out in order to take account of the adaptation of the calculation procedure that was introduced in 2005. This has taken account of the fact that potential methane releases are increasing in keeping with the increasing numbers of decommissioned mines. The resulting methane has been used, in part, since 1998. In future, such use will lead to a considerable reduction of methane emissions in source category 1.B.1.c.

The listed emissions amount consists of an estimate of total emissions from decommissioned mines (experts' assessment: ± 50 %, source: Deutsche Montan Technologie GmbH, DMT 2005), minus the amount of methane used.

3.2.1.3.6 Planned improvements (source-specific) (1.B.1.c)

Via consultations with experts at the NASE workshop 11/2004, the database has been considerably improved. In future, experts' assessments of potential methane emissions will be regularly reviewed.

The comparison of calculation procedures and results from source category 1.A, procedures and results for which BEU data is used, is being applied to improving accuracy, ruling out double counting and enhancing transparency.

3.2.2 Oil and natural gas (1.B.2)

In the CSE, data on fugitive emissions from oil and natural gas is included with data on sub-source categories. Disaggregations relative to the line network are carried out, inter alia, in the CSE (cf. the following Figure). Aggregated information and data are included in the CRF tables (Table 1(s2), 2. Oil and natural gas, and Table 1.B.2 Fugitive emissions from oil, natural gas and other sources).

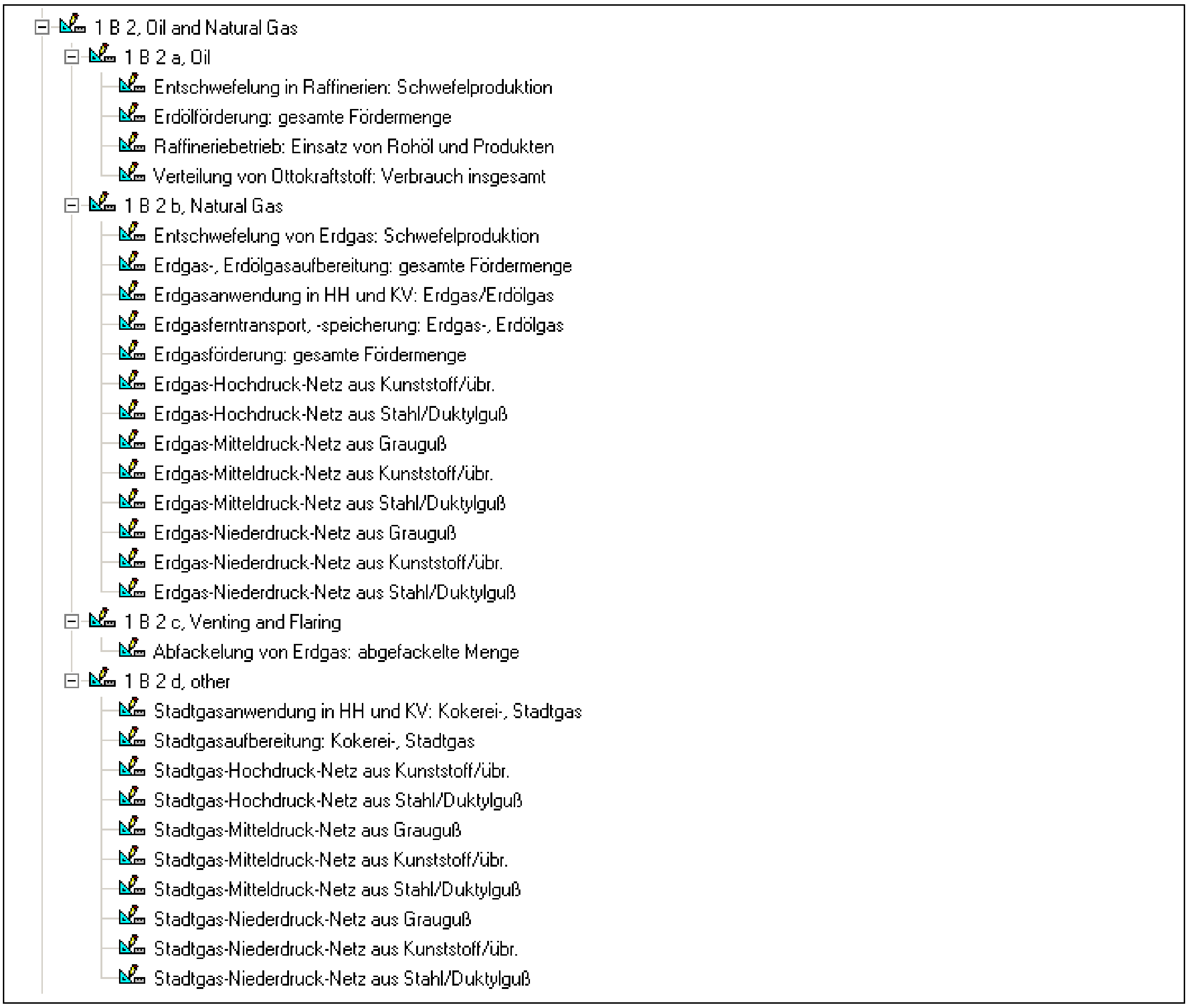


Figure 32: Structural allocation, 1.B.2 Oil and natural gas

CRF 1.B.2					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
1.B.2.b Erdgas (Natural Gas)	l / t	CH_4	0,50 %	0,67 %	rising

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**NMVOC**	**VOC**	**SO_2**
Emission factor (EF)	NO	CS	NO	NO	NO	NO	NO	CS	NO	CS
EF uncertainties in %		25								
Distribution of uncertainties		N								
Method of EF determination		CS								

The source category "Fugitive emissions from oil and natural gas" (1.B.2) is a key category with respect to emissions from natural gas, in light of its emissions levels and trend.

Distribution of natural gas constitutes the principal source of fugitive emissions of CH_4. CH_4 emissions from natural gas extraction and processing, as well as from transfer stations, play a subordinate role in this respect. CH_4 emissions from petroleum extraction and from storage of petroleum products only account for approximately 3 % of emissions from natural gas.

3.2.2.1 Oil (1.B.2.a)

CH_4 emissions from petroleum originate primarily from fugitive emissions from extraction, from the refinery process and from storage of petroleum products. As of the 2004 reporting period, specific emissions from petroleum extraction (sum of 1.B.2.a.i, 1.B.2.a.ii, 1.B.2.a.iii and 1.B.2.c) had decreased only slightly – by 12 % - since 1990. On the other hand, specific fugitive CH_4 emissions from the refinery sector and in-refinery storage of petroleum products (particularly gasoline), including venting losses and flaring emissions, were reduced by 65 % – from 0.06 to 0.02 kg/t – over the same period (1.B.2.a.iv). This is due primarily to introduction of vapour-tight machinery (pumps, compressors), sealing systems (connectors) and vapour-recovery equipment. Overall, CH_4 emissions for source category 1.B.2.a were reduced from 10.8 Gg in 1990 to 6.3 Gg in 2004. The relevant emission factors have not changed from their values in 2004.

To date, it has not been possible to determine the CO_2 emissions for this source category.

3.2.2.1.1 Source-category description: Oil (1.B.2.a)

Crude oil (1.B.2.a.iii) is transported almost exclusively via pipelines. In 2003, the pipeline network for crude oil and petroleum products had a total length of 6,247 km and a total throughput of 154.4 million t. It has not been possible to obtain corresponding figures for 2004; presumably, no significant changes have occurred in this area. As of 2004, the Federal Republic of Germany's network of long-distance pipelines for crude-oil imports had a total length of 1,818 km and a throughput of 105.6 million tonnes of crude oil (MWV, 2005: p. 18 ff).

The IPCC Synthesis and Assessment Report Part I (IPCC, 2004a) noted that the IEF of the source category Refining / storage is lower than those of other Annex I countries. The low IEF for this source category is due to implementation of technical requirements from national legal provisions relative to equipping of systems for storage, transfer and transport of volatile petroleum products. The Technical Instructions on Air Quality Control (TA LUFT, 2002) require the use of structurally tight valves, flanged joints and connections, pumps and compressors, as well as storage of petroleum products in fixed-roof tanks with connections to gas-collection lines.

Only about 0.1 % of all amounts of crude oil used is transported by tanker ships on inland waterways (111,800 t in 2000, cf. DESTATIS Fachserie 8, Reihe 4, 1991-2004). For this reason, this transport pathway has not been included in the present context.

In 2004, a total of 14 crude-oil refineries, and 7 lubricating-oil and used-oil refineries, were in operation in Germany. The total crude-oil input was 122.5 million t in 2004 (MWV, Mineralölzahlen 2004, p. 27).

Source category 1.B.2.a.v "Distribution of petroleum products" is not relevant with regard to CH_4 emissions. Measures such as use of gas-balancing and vapour-recovery systems in fueling of vehicles at petrol stations have virtually eliminated CH_4 emissions in connection with the products petrol/gasoline and crude benzene (naphtha).

3.2.2.1.2 Methodological issues (1.B.2.a)

The CH_4 emissions were determined from the relevant specific emission factors and activity rates.

The CH_4 emission factor for the area of exploration, production and transport of crude oil, 1.1 kg/t crude oil, includes the resulting flaring emissions and vapour losses. It origininates in a research report of the German Society for Petroleum and Coal Science and Technology (DGMK 1992: p. II-98). The CH_4 emission factors for the area of refining and storage were derived from a VOC emission factor (the CH_4 emission factor corresponds to 10 % of the VOC emission factor), and they have continued to be used, due to progress made in emissions-reduction technology. The original VOC emission factor, unfortunately, is not sufficiently well substantiated.

The activity rates have been taken from the National Energy Balance, which is published annually by the Working Group on Energy Balances (AGEB), and from annual special publications of the Mineralölwirtschaftsverband e.V. Association of the German Petroleum Industry ("Mineralöl-Zahlen 2004" and of the Wirtschaftsverband Erdöl- und Erdgasgewinnung German oil and gas industry association ("Jahresbericht Zahlen & Fakten 2004") .

For 1.B.2.a.i Oil exploration and 1.B.2.b Gas exploration, the EF from IPCC GPG may be used (2000: p. 2.86, Table 2.16, line 5); for fugitive emissions from activities relevant to oil and gas, the default emission factor for CO_2, 0.000095 Gg per number of producing and capable wells, may be used, on the basis of North American data for the category "Wells", sub-category "Servicing", emissions type "all", in connection with the AR from the annual report of the Wirtschaftverband Erdöl und Erdgasgewinnung e.V. (WEG) for 2004 (p. 50, Table "Balance of drilling success" (Bohrerfolgsbilanz) – here, the line "Production wells", Total, with 12 strikes for 2004). It was not possible to determine from the literature, at short notice, the numbers of producing wells drilled in the years 1990 to 2003. For this reason, the data from the Balance of producing wells for extraction of oil and natural gas ("Bohrerfolgsbilanz zur Gewinnung von Erdöl und Gas" (op. cit. p. 50, Table "Balance of drilling success" "Bohrerfolgsbilanz") was set in relation to data from "Numbers of exploratory wells drilled for extraction of oil and natural gas" ("Bohrerleistung zur Gewinnung von Erdöl und Gas"), under the assumption that a basic relationship exists between numbers of wells drilled and numbers of strikes. In addition, it was assumed that the available drilling data for the years 2002 through 2004 can be used to establish a mean value for the years 1990 through 2001. With these extremely general assumptions and relationships, the number of well strikes was estimated for the years 1990 through 2003 ("AR" refers to the number of well strikes * DEF 0.000095 Gg = Gg CO_2). Für 2004, this relationship yields 1.14 t CO_2 per well strike (exploration) for oil and gas in Germany. Since the standard EF (see above) and the drilling-success balance for exploration are listed without any breakdown by oil and gas, it was decided to report CO_2 emissions under 1.B.2.a.i Oil exploration and, in the inventory tables for source category 1.B.2.b Gas exploration, to add the remark "IE".

3.2.2.1.3 Uncertainties and time-series consistency (1.B.2.a)

The uncertainties, amounting to 25 %, were determined in the framework of an expert judgement, and they are of the same order as the IPCC GPG default value of $\pm$ 25 % to $\pm$ 50 % (IPCC, 2000: p. 2.92).

3.2.2.1.4 Source-specific quality assurance / control and verification (1.B.2.a)

For source category 1.B.2.a.iv (oil refining / storage), comparison with the IPCC Guidelines' default values (IPCC Guidelines - Reference Manual, 1996b) shows good agreement. Table

1.62 of the Guidelines lists emission factors for this area in a sum ranging from 110 to 1660 kg/PJ. Conversion of the German emission factor for 2004, 0.02 kg/t crude oil, using the lower net calorific value of crude oil (42.7 MJ/kg), produces an emission factor of 468.4 kg/PJ. This value lies within the range for the IPCC default value. Similarly, the emission factor listed by Austria for the year 2000, 0.033 kg/t crude oil, agrees well with the German emission factor determined on a country-specific basis.

For reporting, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents.

3.2.2.1.5 Source-specific recalculations (1.B.2.a)

No recalculations are required.

3.2.2.1.6 Planned improvements (source-specific) (1.B.2.a)

Due to a lack of country-specific emission factors in the area of pipeline oil transports, in future the default values from the IPCC Good Practice Guidance (2000: p 2.87) will initially be used for the Tier 1 approach:

$$EF_{CH4} = 5.4E\text{-}06;$$
$$EF_{CO2} = 4.9E\text{-}07;$$
$$EF_{N2O} = 0$$

[Gg/(10³m³ oil transported per pipeline)]

For the most part, the country-specific activity rates in this area are available in the form of pipeline oil throughputs listed in the MWV's "Oil-industry statistics for 2004" ("Mineralölzahlen 2004") and listed by the MWV in 2000.

Further aspects of inventory completion have been included in the inventory-improvement plan.

3.2.2.2 Natural gas(1.B.2.b)

3.2.2.2.1 Source-category description: Natural gas (1.B.2.b)

This source category includes description of production and processing of natural gas (including onshore and offshore drilling, gas conditioning) as well as description of pertinent pipeline transports and distribution (including long-distance pipelines and local gas networks with their measuring and control stations and compressors) and of natural gas releases at usage sites (residential, commercial/institutional: 1.A.4). In the case of natural gas, the principal source of fugitive CH_4 emissions is distribution of natural gas to the end consumer. Even though the distribution network was expanded, during the period covered by the report, from about 150,000 km to 432,614 km (2003), CH_4 emissions were slightly reduced. This was accomplished via a reduction of about 40 % in fugitive distribution losses. CH_4 emissions in the source category "oil and natural gas" decreased considerably between 1990 (10.8 Gg) and 2002 (4.1 Gg). One explanation for the sharp reduction in methane emissions is that fugitive emissions in refineries were reduced through technical upgrades (tightly sealing fittings, such as flange connections, valves, pumps, compressors) resulting from implementation of emissions-control provisions under relevant regulations (TA Luft 2002, VDI, 2000: VDI Richtlinie (Guideline) 2440).

The other fugitive emissions arising from extraction, processing and high-pressure distribution of natural gas showed only a slight decrease during the period under review. CH4 emissions were reduced overall. Since the overall framework conditions have not changed, only slight changes – if any at all – in emissions for 2003 are to be expected.

Replacement of gray-cast pipelines, a process in which further progress was made, was also a factor in reduction of CH_4 emissions. The German Association of the Gas and Water Industries (DVGW) reports that accidents have been decreasing, over the years, in the area of gas supply to residential and commercial/institutional. At the same time, it notes that accidents have been concentrated in two areas. These two areas are "backhoe damage" occurring during excavation related to household gas connections and tampering with household gas systems. During the year under consideration, a total of 23 pore reservoirs and 20 cavern reservoirs for natural gas were in operation. Within the latter group, a total of 145 individual caves were used. Following a slight decrease in 2002, the working gas volume of underground reservoirs increased slightly in 2003 – by 0.7 billion m³ (V_n), to 19.6 billion m³ (V_n). Of this volume, a maximum of 18.6 billion m³ (V_n) are currently technically usable. Current planning calls for an additional 3.5 billion m³ (V_n) of working-gas storage capacity to be installed, primarily in the form of cavern reservoirs. The major projects underway since the early 1990s have now largely been completed, and the working-gas volume has been stable for several years as a result.

The sub- source category "Other leakage" includes emissions occurring in household use of natural gas.

3.2.2.2.2 Methodological issues (1.B.2.b)

The CH_4 emissions for natural gas were determined from the relevant specific emission factors and activity rates. The activity rates originate predominantly from the National Energy Balance published annually by the Working Group on Energy Balances (AGEB, 2004). Activity rates for calculation of emissions from natural-gas transport / distribution are determined with the help of gas statistics of the Federal Association of the German Gas and Water Industry (Bundesverband der deutschen Gas- und Wasserwirtschaft; BGW). On the basis of these gas statistics, the activity rates are determined first, via intermediate steps, for the existing time series. These intermediate steps are needed for the National Inventory, since certain activity rates are no longer included in gas statistics. In addition, the annual reports of the Wirtschaftsverband Erdöl- und Erdgasgewinnung e.V. German oil and gas industry association were evaluated.

The specific emission factors were derived by the Federal Environmental Agency, on the basis of research in the literature (SCHÖN, WALZ et al., 1993) and among relevant companies, and they have been continually used.

NMVOC emissions in the gas sector have not been determined to date.

Regarding 1.B.2.b Gas exploration, the reader is referred to Chapter 3.2.2.1.2 – the paragraph on 1.B.2.a.i Oil exploration.

CO_2 emissions also occur in processing of acid gas (1.B.2.b.i Gas production / processing). This is indicated by figures provided by other countries for this sub- source category. The rough estimate of these emissions draws on petroleum-industry information whereby an estimated 75 % of the gas produced in Germany is processed, as acid gas, in desulpherisation plants. In this percentage estimate, it is assumed that the three gas-processing plants located in Großkneten, Rütenbrock and Vogtei process acid gas produced in Germany. The two plants located in Großkneten and Voigtei, operated by ExxonMobil Production Deutschland GmbH, processed about 14.5 billion cubic metres in 2003 (nearly two-thirds of Germany's natural-gas production) (EXXONMOBIL, 2006). On this basis, the activity rate for natural-gas extraction can be set at 75 %. The relevant emission factor can be derived from figures in the inventory for Austria. In its NIR, that country explains its emission factors for the period 1990 to 2003 (cf. UNFCCC, 2006: Austria, NIR 2005, p. 126). Other inventories studied, along with the pertinent inventory reports, provide no information regarding calculation procedures, or useful explanations, relative to the CO_2 emissions in this sub- source category. Since fall 1972, when its first expansion for gas purification went into operation, the natural-gas-processing plant in Großenkneten has become an important part of Germany's natural gas supply system. Along with a gas-purification system that went into operation in 1979, and with yet another such system that was added in 1994, that plant is now one of the world's largest, most modern and most environmentally friendly natural-gas-purification plants (BVB VERLAGSGESELLSCHAFT, 2006). Unfortunately, no information abou the natural-gas-processing plant in Rütenbrock (community of Haren) is available at present. That plant is also assumed to have gone into operation prior to 1990. The NEAG natural-gas-processing plant in Voigtei (in the Nienburg rural district) went into operation in 1963, in the immediate vicinity of the NEAG gas-purification plant (STEINBRUCHS-BERUFSGENOSSENSCHAFT, 2003; EXXONMOBIL, 2000). All plants were in operation as of 1990. The AR for natural-gas extraction has been taken from the annual report of the Wirtschaftverband Erdöl und Erdgasgewinnung e.V. German oil and gas industry association (WEG) for 2004, p. 42, Table "Development of natural-gas production" ("Entwicklung der Erdgasförderung").

Calculation procedure:

$$\text{AR 75\% natural gas production (including acid gas) in 1,000 m}^3 \text{ * EF 4,000.00 Gg / 1,000 m}^3 \text{ (acid gas) = EM CO}_2 \text{ Gg}$$

The CO_2 emissions for sub- source category 1.B.2.b.ii Gas transmission are not reported, because the emissions are insignificant – the category lacks relevant emissions sources. Other countries, including Denmark, Portugal, Sweden, Slovakia, Ireland, Hungary, Finland, Lichtenstein and Croatia, report "NO" for this category, while still other countries, including Norway, New Zealand and the U.S., report "IE". These reports do not provide any useful information in this area relative to Germany's inventory preparation, however. CO_2 emissions of sub- source category 1.B.2.b. Gas transmission (here: Distribution) are also not reported, because they are insignificant – the category lacks relevant emissions sources.

3.2.2.2.3 Uncertainties and time-series consistency (1.B.2.b)

The uncertainties, amounting to 25 %, were determined by Federal Environmental Agency experts in the framework of an "expert judgement", and they are of the same order as the IPCC Good Practice Guidance default value.

3.2.2.2.4 Source-specific quality assurance / control and verification (1.B.2.b)

As to source category 1.B.2.b (natural gas production, processing and distribution), Table 1.62 of the IPCC Guidelines (1996b) lists only a default value for the emission factor for the entire source category – 58,000 to 111,000 kg/PJ. A comparison with the summed German emission factors converted using the lower net calorific value of natural gas (35.7 MJ/Nm³) shows good agreement. The country-specific determination produced an overall emission factor that lies within the lower range of the spread for the IPCC default value.

The country-specific emission factor of 27,000 kg/PJ for natural-gas extraction has not been adequately substantiated to date.

Some values for 2004 were obtained via calculation or via continued use of values from previous years.

For reporting, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents.

3.2.2.2.5 Source-specific recalculations (1.B.2.b)

No recalculations are required.

3.2.2.2.6 Planned improvements (source-specific) (1.B.2.b)

The emissions-calculation procedures are to be reviewed and adjusted in the interest of inventory completion.

As to the lacking information on CO_2 emissions, as of 2006 data obtained in the framework of transposition of the European directive on emissions trading is to be included (Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community). Plans call for supplanting emission factors for natural-gas distribution with more current factors, obtained from another source.

Findings from a planned research project will be used to improve the data from the energy balance for the Federal Republic of Germany. The possibility of using industry-association data is to be reviewed.

3.2.2.3 Venting and flaring (1.B2.c)

CH_4 emissions from flaring and venting (vapour losses) have already been covered in the relevant previous sections of the NIR (1.B.2.a and 1.B.2.b).

CO_2 emissions for this source category have not been determined to date.

3.2.2.3.1 Source-category description: Venting and flaring (1.B.2.c)

At present, emissions from venting and flaring of oil during direct further processing (refinery flaring) are reported in source category 1.B.2.a.ii. No activity rates and emission factors for emissions during exploration are known.

3.2.2.3.2 Methodological issues (1.B.2.c)

Emissions from venting and flaring of natural gas are included in source categories 1.B.2.a and 1.B.2.b.

3.2.2.3.3 Uncertainties and time-series consistency (1.B.2.c)

The relevant statements made in chapters 1.B.2.a and 1.B.2.b also apply here to uncertainties relative to emissions from venting and flaring.

3.2.2.3.4 Source-specific quality assurance / control and verification (1.B.2.c)

For reporting, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents.

3.2.2.3.5 Source-specific recalculations (1.B.2.c)

No recalculations are required.

3.2.2.3.6 Planned improvements (source-specific) (1.B.2.c)

Further studies relative to activity data and CH_4 and CO_2 emissions are planned. The DEHSt data source, which may be useful for this purpose, will not become available prior to the NIR 2007 (CO_2 monitoring is included in that source only as of 2005). Further aspects of inventory completion have been included in the inventory-improvement plan.

4 INDUSTRIAL PROCESSES (CRF SECTOR 2)

4.1 Mineral products (2.A)

Source category 2.A Mineral products is divided into the sub-categories 2.A.1 through 2.A.7. Of these, the CSE includes Cement production, divided into cement clinker production and cement production (2.A.1), Lime production (2.A.2), Soda ash production and use (2.A.4), Road paving with asphalt (2.A.6) and, under Other (2.A.7), glass production, coarse ceramics and salt and potassium salt production.

Limestone and dolomite use (2.A.3) and Asphalt roofing (2.A.5) are not included.

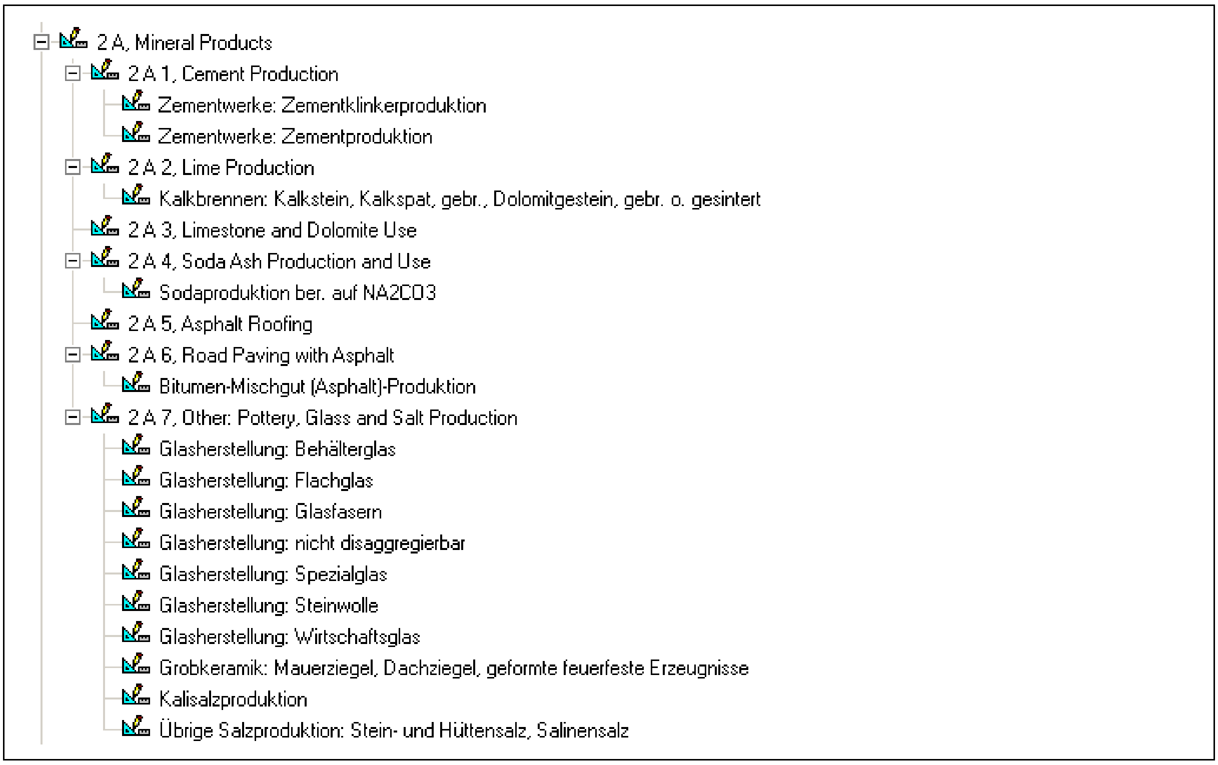


Figure 33: Structural allocation, 2.A Mineral products

4.1.1 Mineral Products: Cement (2.A.1)

4.1.1.1 Source-category description (2.A.1)

CRF 2.A.1					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
Cement production	l / t	CO_2	1,19 %	1,33 %	rising

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	CS	NO	NO	NO	NO	NO	NO	NO	NO	NE
EF uncertainties in %	± 10	- -	- -	- -	- -	- -				
Distribution of uncertainties		- -	- -	- -	- -	- -				
Method of EF determination	CS	- -	- -	- -	- -	- -				

In light of its emissions levels and trend, the source category "Cement" (2.A.1c) is a key category.

In 2003, a total of 69 ovens for burning of cement clinkers, with a total capacity of 130,020 t/d, were in operation throughout Germany. In a breakdown by oven types, the largest group of these consisted of ovens with cyclonic preheaters (45), followed by ovens with grid preheaters (16) and shaft ovens (8) (BDZ, 2004a, p. 7). A total of 31 companies, with 47 cement plants in Germany, are members of the Association of the German Cement Industry (Bundesverband der Deutschen Zementindustrie - BDZ, 2005b).

In the CSE, two different structural elements for the area of "cement" are used. The AR time series for cement production are designed to take account of dust emissions, because grinding of clinkers, as a dust source, must be considered independently from the amount of clinkers burned in Germany. These time series have no relevance with regard to the greenhouse-gas inventory. The relevant time series are those for the structural element "cement-clinker production" – and the remarks made in the following section refer to these. At the same time, it must be noted that considerable amounts of foundry sand (5.11 million t in 2004), a by-product of steel-making, are used in cement production in place of cement clinkers. In such use, 1 t of foundry sand replaces 1 t of cement clinkers, and this relationship defines the pertinent CO_2-emissions reductions (AICHINGER, 2005: p. 31f).

The clinker-burning process emits climate-relevant gases. CO_2 accounts for the great majority of these emissions. According to a preliminary figure of the National association of the German cement industry (BDZ; 2005), clinker production in 2004 amounted to 26,281 kt. The pertinent raw-material-related CO_2-emissions are calculated with the help of a country-specific emission factor, 0.53 t CO_2/t cement clinkers, that was determined by the German Cement Works Association (Verein Deutscher Zementwerke; VDZ) from plant-specific data. Clinker production produced raw-materials-dependent CO_2 emissions of 13,929 kt CO_2 in 2004.

4.1.1.2 Methodological issues (2.A.1)

The activity rates data was compiled by the German Cement Works Association, *Verein Deutscher Zementwerke e.V.* (VDZ; i.e. by their cement-industry research institute)/Düsseldorf, by means of surveys amongst German cement factories and via use of BDZ figures. In the main, the data consists of data published in the framework of CO_2 monitoring (VDZ, 2005), and supplemented with data for plants that are not BDZ members (in part, also VDZ estimates). For the years 1991 to 1993, the activity rates exhibit a data gap that the association (VDZ) cannot close. These years have been interpolated in the inventory.

Table 38 summarises the activity rates, and the raw-material-related CO_2 emissions as determined from clinker production, for the years 1987 through 2004. The clinker factor (*t clinkers /t cement)* cannot be calculated from the figures in the table, since part of the clinkers produced in Germany are exported and thus do not show up in figures for cement production. In 2004, the clinker factor was 81.7 %, which was somewhat higher than in the previous years (ca. 78 %).

Table 38: Activity rates and resulting CO_2 emissions of the German cement industry, for the years 1987-2002

Year	Clinker production	Cement production from German clinkers	Raw-material-related CO_2 emissions
	[kt/a]	[kt/a]	[kt/a]
1987	29.039	37.698	15.391
1988	29.876	38.725	15.834
1989	31.377	40.728	16.630
1990	28.577	37.772	15.146
1991	25.670	34.341	13.605
1992	26.983	37.331	14.301
1993	27.146	36.649	14.387
1994	28.658	40.512	15.189
1995	29.072	37.480	15.408
1996	27.669	35.845	14.664
1997	28.535	35.932	15.124
1998	29.039	36.378	15.391
1999	29.462	38.099	15.615
2000	28.494	36.311	15.102
2001	25.227	32.081	13.370
2002	23.954	30.485	12.696
2003	25.233	32.243	13.373
2004	26.281	31.391	13.929

Source: VDZ, 2005

The emission factor used for emissions calculation, 0.53 t CO_2 / t cement clinkers, is based on a source-category-specific, *bottom-up* approach, i.e. the VDZ determined the emission factor by aggregating plant-specific data relative to fractions of CaO and other metal oxides (MgO; as raw materials, containing carbonate). 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 German emission factor's (small) deviation from the prescribed default value, 0.5071 t CO_2 / t clinker, results from German clinkers' frequently higher lime content (64 % to 67 % CaO) and from inclusion of an average MgO content of 1.5% (which the default value does not include). The procedure corresponds to the Tier 2 method of the *IPCC-GPG* (IPCC, 2001). The aforementioned emission factor of 0.53 t CO_2 / t cement clinkers is also used in the German industry's CO_2-monitoring reports and in calculations in the framework of greenhouse-gas emissions trading.

Raw-material-related CO_2 emissions released through limestone deacidification in the cement industry were determined, pursuant to *IPCC-GPG*, using the following equation, where the emission factor itself was adjusted to take account of country-specific conditions:

$$CO_2 \text{ emissions} = \text{emission factor } (EF_{clinkers}) \text{ x clinker production}$$

Table 38 shows the German cement industry's raw-material-related CO_2 emissions for the years 1987 to 2003, as calculated – by way of example – using the above-described method. The emission factor of 0.53 t CO_2 / t cement clinkers was applied to the entire time series.

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

Conversion, since the NIR 2004, to activity data from "bottom-up" surveys, carried out in the framework of German industry's CO_2 monitoring, has made possible realistic calculations within the CSE and consistent descriptions in the NIR. Uncertainties still persist in determination of activity rates, however, since some of the data can only be estimated, using plant data of the VDZ.

With regard to the time-series consistency, cf. also Chapter 4.1.1.6.

The listed uncertainties were determined via experts' assessment pursuant to Tier 1 of the IPCC GPG rules (2001: Chapter 6.3 p. 6.12).

The uncertainty for the activity rates used was estimated as +/– 7 %. This experts' assessment took account of the following error sources:

- Uncertainty in collecting and transferring data,
- Uncertainties in determination of activity rates, since some of the data can only be estimated, using plant data of the VDZ.

The uncertainty for the emission factors used was estimated as +/– 10 %. This experts' assessment took account of the following error sources:

- The uncertainty relative to the average fractions of limestone and other carbonates in the clinker raw materials.

4.1.1.4 Source-specific quality assurance / control and verification (2.A.1)

In the NIR 2004, the calculation procedure for the cement industry was adjusted and the relevant bases for calculation were adapted. Previously, the data published in "Environmental data of the German cement industry" was used. In an additional review, it was found that those statistics covered only the producers registered within the association. The actual figures were higher, however. For this reason, the VDZ data provided for the CO_2 monitoring report seemed more suitable, since it refers to the amount of cement clinkers produced in Germany. In the interest of greater precision and clarity, a shift was made in the choice of database, to the association figures for the CO_2-monitoring report.

For purposes of quality assurance, all data used, including data from the BDZ, VDZ and from the literature, was checked for plausibility. The determined emission factor for raw-material-related CO_2 emissions has been compared with the relevant figures of other countries. Good agreement was found with figures from Australia, Canada, Denmark, France, Ireland, Spain, the UK and the U.S.. The small deviation (< 5 %) from the IPCC Tier 1 default factor of the IPCC Reference Manual (IPCC et al, 1997: Chapter 2.3.2, p. 2.6) results from somewhat higher average carbonate content of clinker raw materials in Germany (see above).

4.1.1.5 Source-specific recalculations (2.A.1)

No source-specific recalculations in the area of cement-clinker production were required.

4.1.1.6 Planned improvements (source-specific) (2.A.1)

The emission factor of 0.53 t CO_2 / t clinker, which was used for the entire time series, is to be verified on the basis of plant-specific data on the carbonate content of clinker raw materials and of the metal-oxide content of produced clinkers.

In future, an emission factor for raw-material-related SO_2 emissions will also be entered into the CSE. The relevant surveys and calculations that must be carried out in advance for that purpose have not yet been completed, however.

4.1.2 Mineral Products: Lime production (2.A.2)

4.1.2.1 Source-category description (2.A.2)

CRF 2.A.2					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
Lime production	l / -	CO_2	0,48 %	0,53 %	rising

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	D	NO	NO	NO	NO	NO	NO	NO	NO	NE
EF uncertainties in %	+5/-10	--	--	--	--	--				
Distribution of uncertainties	L	--	--	--	--	--				
Method of EF determination	D	--	--	--	--	--				

Source category 2.A.2 is a key category in terms of its CO_2-emissions levels.

Lime results from burning of limestone. The primary component of limestone is calcium carbonate.

Dolomite lime is produced via burning of dolomite. Chemically, dolomite is a mixture of calcium carbonate and magnesium carbonate. No plants for burning pure magnesium carbonate (*dead-burned magnesia*) are operated in Germany.

Lime and its secondary products (such as lime hydrate) and dolomite lime are used in many areas, including the steel industry, the chemical industry, environmental protection (for example, in flue-gas desulphurisation in power stations and in wastewater treatment) and agriculture.

The statements made below regarding source category 2.A.2 refer solely to the amounts of burnt lime and dolomite lime produced in German lime works. Information about other lime-producing and lime-using sectors is provided in Chapter 2.A.3, in the interest of preserving the international comparability of Chapter 2.A.2.

In the main, lime production consists of the process steps preparation (crushing, classing, washing) and calcination (burning). Part of the resulting lumpy lime is subsequently ground (fine lime) or slaked to form lime hydrate. During the burning process, carbon dioxide is released at high temperatures from the limestone or dolomite. The carbon dioxide is gaseous and is released into the atmosphere.

Lime production:

$$CaCO_3 + \text{heat energy} \rightarrow CaO + CO_2$$

Dolomite lime production:

$$CaCO_3 \bullet MgCO_3 + \text{heat energy} \rightarrow CaO \bullet MgO + 2\ CO_2$$

Due to relevant products' broad range of uses, lime production is normally less subject to economic fluctuation than is production of other mineral products, such as cement. Lime production did decrease in the years following the base year, 1990, however. This was a result of the sector's restructuring following German reunification, as well as of economic factors and of development of competing and substitute products. Following a brief increase in the mid-1990s, production then again decreased. In the years 2000-2004, about 6.5 million t of lime were produced, i.e. the fluctuations of the past few years have been small.

Between 1990 (the base year) and 2004, production decreased by about 9 %.

Dolomite-lime production, of which significantly smaller amounts are produced, exhibits similar fluctuations. At the same time, production in 2003 and 2004 decreased sharply from its levels in the two immediately preceding years (about 15 %). Between 1990 (the base year) and 2004, production decreased by about 22 %.

With a constant emission factor, 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.

4.1.2.2 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 amount is obtained by multiplying the amount of product in question (total amount of lime and dolomite lime) and the relevant emission factor.

CO_2 emissions = emission factor (EF) x total amount of lime and dolomite lime

The applicable emission factor is calculated from the pertinent shares of lime or dolomite lime with respect to the entire production amount, and from the stoichiometric emission factors for the individual products concerned:

EF_{lime} : *0.785 t CO_2/t lime*

$EF_{dolomite\ lime}$: *0.913 t CO_2/t dolomite lime*.

Here, it is assumed that the 100 % of the lime consists of CaO, and that 100 % of the dolomite lime consists of CaO • MgO. These assumptions are in keeping with stoichiometric release of CO_2. This approach can lead to overestimation of emissions, since it does not take account of any impurities in the relevant raw materials or of any incomplete deacidification. In principle, this approach corresponds to the specifications of the IPPC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (Chapter 3.1.2). In 2004[19] , total lime and dolomite lime production amounted to 6.97 million t. This resulted in total CO_2 emissions of 5.53 million t.

[19] Preliminary figure of the German Lime Association (BVK)

Table 39 Production and CO_2 emissions in the German lime industry

	Lime		Dolomite lime		Total		Year-specific, mixed EF (lime/dolomite)
Year	Production [t]	CO_2 em. [millions of t]	Production [t]	CO_2 em. [millions of t]	Production [t]	CO_2 em. [millions of t]	
1990	7.129.000	5,596	590.103	0,539	7.719.103	6,135	794,8
1991	6.303.335	4,948	591.824	0,540	6.895.159	5,488	796,0
1992	6.396.407	5,021	574.502	0,525	6.970.909	5,546	795,5
1993	6.668.149	5,234	515.167	0,470	7.183.316	5,705	794,2
1994	7.312.766	5,741	504.719	0,461	7.817.485	6,201	793,3
1995	7.411.000	5,818	543.651	0,496	7.954.651	6,314	793,7
1996	6.832.000	5,363	544.199	0,497	7.376.199	5,860	794,4
1997	6.926.000	5,437	529.928	0,484	7.455.928	5,921	794,1
1998	6.619.100	5,196	556.965	0,509	7.176.065	5,705	794,9
1999	6.629.306	5,204	479.909	0,438	7.109.215	5,642	793,6
2000	6.803.540	5,341	524.196	0,479	7.327.736	5,819	794,2
2001	6.482.592	5,089	511.234	0,467	6.993.826	5,556	794,4
2002	6.412.235	5,034	514.969	0,470	6.927.204	5,504	794,5
2003	6.549.476	5,141	435.785	0,398	6.985.261	5,539	793,0
2004	6.510.674	5,111	458.520	0,419	6.969.194	5,530	793,4

Mean $EF_{lime/dolomite}$	**794,3**
Minimum	793,0
Maximum	796,0

Source: BV KALK, 2005

The applicable mixed emission factor for lime and dolomite-lime production is calculation via the following formula:

$$mixed\ EF_{lime\ /\ dolomite} = \frac{product\ amount_{lime} * EF_{lime} + product\ amount_{dolomie\ lime} * EF_{dolomite\ lime}}{product\ amount_{lime} + product\ amount_{dolomite\ lime}}$$

The resulting values, calculated specifically for each relevant year (see the right column of Table 39) show only minimal spreading (ranging from 793.0 and 796.0 t CO_2 / t total lime; arithmetic mean: 794.3 t CO_2/t total lime).

The figures for lime and dolomite-lime production are collected by the German Lime Association (BVK) on a per-plant basis and then provided annually in aggregated form. For the years until 1994, no separate dolomite-lime production figures are available for the old and new German Länder; the relevant figures were estimated from the dolomite lime's share of total lime production and from the known total activities in the old and new German Länder. This artificial breakdown has no impact on the CO_2 emissions to be calculated, since the same emission factors (derived stoichiometrically) are used for both old and new German Länder.

No details are available as to the impurities in the raw materials and the pertinent degrees of deacidification. To permit comparison with other required reporting areas in which the same assumptions are applied, a CaO / CaO • MgO content of 100 % is assumed (= no impurities, complete deacidification).

Emissions from hydraulic-lime production play an insignificant role in Germany and are not estimated.

4.1.2.3 Uncertainties and time-series consistency (2.A.2)

The German Lime Association (BVK) collects the production data for the entire time series and makes it available for reporting purposes. Production amounts are determined via any one of several different means and thus their quality is adequately assured. The data for two smaller plants (one lime producer and one dolomite-lime producer) cannot be included throughout the entire time series. They are considered to account for a comparatively small share of production, however, and this fact has already been taken into account via the uncertainties estimate.

Stoichiometric emission factors were used, throughout the entire time series, to determine pertinent CO_2 emissions.

The uncertainties for the activity rates used were estimated as -5 % and +7 %. The following factors entered into this experts' assessment:

1. The production figures for two, smaller producers are not available, throughout the entire time series. This causes the activity rate to be underestimated.
2. The production data collected by the German Lime Association (BVK) is subject to only slight errors, since pertinent comparative surveys have been carried out (by various means).
3. The uncertainties estimate also includes the usual measuring and documentation errors.
4. Emissions from hydraulic-lime production have not been included, because they are insignificant.

The uncertainties for the emission factors used were estimated as -10 % and +5 %. The following factors entered into this experts' assessment:

1. In estimation of CO_2 emissions, stoichiometric release of CO_2 from the limestone and dolomite is assumed. As a result, the emissions are overestimated; incomplete deacidification is not taken into account.
2. In use of stoichiometric factors, raw-material impurities and differences in carbonate content are not taken into account. This can lead to overestimation or underestimation of emissions.

4.1.2.4 Source-specific quality assurance / control and verification (2.A.2)

The estimated emissions and collected production-amount data were compared with findings from emissions trading and with national statistical data. The emission factors used were compared with the IPPC default factors. Both reviews confirmed the method used and the country-specific emission factor.

For reporting under CRF 2.A.2, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents.

4.1.2.5 Source-specific recalculations (2.A.2)

The emissions for source category 2.A.2 were recalculated for the entire time series. This was done to account for the more complete source-category coverage provided by the production figures. Product-specific production amounts are now available for lime and dolomite lime. In all previous reporting, only the production amounts of lime (i.e. not including dolomite lime) were taken into account. Production of one dolomite-lime plant that is not an association member was taken into account only in projection of association data. Furthermore, in emissions calculation, the stoichiometric factor for lime production was used for the entire production amount. The recalculation, covering the entire time series, shows that the data is significantly improved. Summary figures are available for production of lime and dolomite lime. These were used, in combination with the proportionately averaged emission factor, to determine the total emissions for source category 2.A.2.

4.1.2.6 Planned improvements (source-specific) (2.A.2)

The product-specific activity rates available now (and in future) for lime and dolomite lime make it possible to systematically break down the emissions calculation by lime production and dolomite-lime production. In future, suitable breakdown of the time series in the CSE will make it possible to enter the data provided by the lime-industry association directly into the CSE; to calculate the emissions for both products, using the stoichiometric emission factors; and then to form the sum of the two partial amounts. While this approach will not yield any different emissions values, it will be more transparent and it will involve fewer advance calculation steps (the mixed calculation for emission factors described in Chapter 4.1.2.2 will then no longer be required). The necessary changes in the CSE will be implemented by the 2007 reporting round.

4.1.3 Mineral Products: Limestone and dolomite use (2.A.3)

4.1.3.1 Source-category description (2.A.3)

CRF 2.A.3					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
	- / -				

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	IE	NO	NO	NO	NO	NO	NO	NO	NO	NO
EF uncertainties in %	--	--	--	--	--	--				
Distribution of uncertainties	--	--	--	--	--	--				
Method of EF determination	--	--	--	--	--	--				

At present, emissions of this source category are not reported separately; instead, they are reported in the source categories that use limestone and dolomite. Where burnt lime is used in source categories, the CO_2 released in the burning process is already included in the emissions for source category 2.A.2. Other emissions, apart from CO_2, are not considered in this source category.

In the framework of a research project entitled "limestone balance" ("Kalksteinbilanz"), all use of limestone and dolomite is currently being systematically balanced. In addition, suitable, annually available data sources are being selected for future reporting, and the relevant calculations are being integrated within the national reporting system. In this source category, all production and use of limestone and dolomite is being considered in balance form, and the results are being compared with the inventory source categories. The source category is being sub-divided with a view to the IPCC 2006 Guidelines (Volume IPPU), which delegate calculation of CO_2 emissions into the responsible source categories. For simplicity, only "limestone" is referred to (apart from a few exceptions that require special explanation), even when a combination of limestone and dolomite is meant.

The "limestone balance" project provides a substance-flow analysis, in the form of amounts balances that can be combined into time series, without any methodological discontinuities. This methodological work is being carried out in a research project that is drawing on all of the Federal Environmental Agency's available expertise (UBA, FKZ 20541217/02[20]).

4.1.3.2 Methodological issues (2.A.3)

In the "limestone balance" research project, input amounts have been modelled for all important limestone-using source categories i.e. the original data on limestone use is not available in the form of suitable statistics, at least not at the project's current stage. The data can usually be calculated with production data, however, and thus obtained for the limestone balance.

The prepared balance clearly shows what errors the emissions inventory previously contained:

Table 40: 2.A.3: preliminary limestone balance for relevant areas, for the years 1990, 1995 and 2004

Amounts of limestone used in balance position / areas [in millions of t]	1990	1995	2004
1A1a Limestone-flue-gas desulphurisation	1,1	2,3	4,0
2A1 Burning of cement clinkers	33,3	33,9	30,7
2A2 Burning of limestone and dolomite	13,8	14,2	12,5
2A4 Soda-ash production	2,3	1,8	1,7
2A7 Glass production	0,6	0,9	0,9
2B5 Fertiliser production	1,1	0,9	0,7
2C1 Iron and steel production	5,4	5,1	5,1
2D2 Sugar production	0,7	0,8	0,8
5D Soil liming in agriculture and forestry	1,7	2,4	2,7

The balance sum is still undergoing specialised review and is not shown here. The balance positions from source categories 1.A.1.a and 2.C.1 have been identified as relevant emissions sources. In addition, one error was identified via the so-called "auxiliary balance": In it, the limestone share in the raw materials has been estimated, because the relevant amount is not included in limestone production and thus is not taken into account in the limestone balance..

Table 41: 2.A.3: Auxiliary balance for limestone input, in raw materials, in brick production

Limestone input in raw meal [in millions of t]	1990	1995	2004
2 A7 Brick production (masonry bricks and roof tiles)	1,11	1,52	1,08

Source: Calculations from the "limestone balance" project ("Kalksteinbilanz";UBA 2006, FKZ 20541217/02); cf. 4.1.8

The inventory gaps were closed with the obtained data, and the relevant methodological aspects are described in the pertinent source category chapters (cf. 3.1.1.2, 4.1.8.2, 4.3.1.2, 4.1.8.2).

[20] In progress: the research project "Balancing of production and use of limestone, and listing of CO_2 emissions" ("Bilanzierung der Gewinnung und Verwendung von Kalkstein und Ausweisung der CO_2-Emissionen"), FKZ 20541217/02

4.1.3.3 Uncertainties and time-series consistency (2.A.3)

The uncertainties lie primarily in the activity data, because the source-category modelling is not yet completed. The emission factors are determined from the stoichiometry of the carbonates, with complete decarbonisation, and are thus adequately precise.

4.1.3.4 Source-specific quality assurance / control and verification (2.A.3)

The source category has already been made conformal with the requirements of the CSE manual and its applicable accompanying documents. The relevant incompleteness, and the necessary improvements, were described prior to the project's commencement.

The limestone-balance activity data is verified in the relevant source categories. In general, verification with limestone-production statistics (not yet included in Table 40 attests to the accuracy of the preliminary balance.

4.1.3.5 Source-specific recalculations (2.A.3)

Recalculations are being carried out in the relevant source categories.

4.1.3.6 Planned improvements (source-specific) (2.A.3)

The "limestone balance" project (cf. Chapter 4.1.3.1) has not yet been concluded, in order to permit additional specialists to take part in it. Association figures, and emissions-trading data, are particularly significant with regard to verifications.

For reporting in 2007, an effort will be made, where possible, to refine emissions calculation or to use original statistical data instead of models.

4.1.4 Mineral Products: Soda ash production and use (2.A.4)

4.1.4.1 Source-category description (2.A.4)

CRF 2.A.4					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
	- / -				

Gas	CO_2	CH_4	HFC	PFC	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)	0	NO	NO	NO	NO	NO	NO	NO	NO	NO
EF uncertainties in %	0									
Distribution of uncertainties	N									
Method of EF determination	D									

The source category "Soda ash production and use" (2.A.4) is not a key category.

In Germany, soda ash is produced only chemically. The country has 3 production facilities, all of which use the Solvay process. With respect to the calcium carbonate it uses, this process is CO_2-neutral, since the carbon dioxide in the limestone is bound within the product, soda ash (Na_2CO_3), and is released only during product use.

On the other hand, coke is used in the calcination part of the process, and this produces additional carbon-dioxide emissions. An amount of some 100 kg of coke is assumed per tonne of soda ash; this was determined in a research project in the framework of the BVT's preparation of information sheets (UBA: German Notes on BAT for the production of Large Volume Solid Inorganic Chemicals – Soda, 2001). While this corresponds to an amount of some 380 kg CO_2 / t soda ash, these emissions are reported not here but together with energy-related emissions.

Soda ash is used in a wide range of industrial applications. The most important application areas include the glass industry, metallurgy, production of detergents and cleansers, the chemical industry and exhaust-gas and wastewater treatment. In many cases, hydrogen carbonate is released in wastewater, but such releases are not climate-relevant. In addition, a significant share (8 - 25 %) of production is exported.

Emissions from soda-ash use are taken into account source-specifically and, where they are relevant, are included in the emission factors for the industries concerned (glass industry). No detailed information is available about the pertinent consumer groups and about possible releases, as CO_2, into the atmosphere (bottom-up approach).

4.1.4.2 Methodological issues (2.A.4)

The Federal Statistical Office (DESTATIS) determines the total amounts of soda ash produced in Germany. Since 1995, the sum total has comprised the categories of light soda and heavy soda (production numbers – 2413 33 103, disodium carbonate in powder form, with a fill density of less than 700 g/l; and 2413 33 109 other disodium carbonate). Of these amounts, only the portion "intended for sale" – and not the entire amount produced – is taken into account. This prevents double-counting, since heavy soda is produced from light soda (agreement between DESTATIS and the manufacturers). Only estimated figures are available for production in the new German Länder until 1994.

Since the Solvay production process is neutral with regard to CO_2, an emission factor of "0" is used for production.

The amounts of coke that are converted into CO_2 during lime burning are already taken into account, with regard to their CO_2 emissions, in the Energy Balance.

Emissions from soda-ash use are included source-specifically; for this reason, no emission factor is given here (top-down approach) (IE: included elsewhere).

4.1.4.3 Uncertainties and time-series consistency (2.A.4)

Activity data: There are uncertainties regarding the production statistics given by DESTATIS, since – for example – the relation between light and heavy soda fluctuates widely, especially in the first years for which separate statistics are provided.

Consistency is not complete, due to the described need to estimate production amounts in the new German Länder. What is more, a break in time-series consistency occurs: initially, sales comprised nearly all of the total amount produced; in 1995, when production statistics were changed, sales dropped to about 2/3 of total production, however, and now they account for only about 50 % of production.

The total uncertainty is estimated at 20 %.

Emission factor: Since the emission factor is a justified "zero", there is no uncertainty.

4.1.4.4 Source-specific quality assurance / control and verification (2.A.4)

For reporting under CRF 2.A.4, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents.

4.1.4.5 Source-specific recalculations (2.A.4)

Since the emission factor for CO_2 has been changed from 380 kg/t to 0 kg/t, source-specific recalculation is required this year. This corrects previous double-counting in process-related and energy-related emissions.

This reduces annual CO_2 emissions by over 500,000 tonnes of CO_2. The cumulative reduction since the base year is nearly nine million t of CO_2.

4.1.4.6 Planned improvements (source-specific) (2.A.4)

No improvements are planned at present.

4.1.5 Mineral Products: Asphalt roofing (2.A.5)

Emissions from this source category are currently not being reported.

4.1.5.1 Source-category description (2.A.5)

4.1.5.2 Methodological issues (2.A.5)

4.1.5.3 Uncertainties and time-series consistency (2.A.5)

4.1.5.4 Source-specific quality assurance / control and verification (2.A.5)

4.1.5.5 Source-specific recalculations (2.A.5)

4.1.5.6 Planned improvements (source-specific) (2.A.5)

Germany plans to calculate emissions for this source category as of 2007 reporting.

4.1.6 Mineral Products: Road paving with asphalt (2.A.6)

CRF 2.A.6					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
	- / -				

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	NO	NO	NO	NO	NO	NO	NE	NE	CS	NE
EF uncertainties in %										
Distribution of uncertainties										
Method of EF determination										

As far as is currently known, the source category Road paving with asphalt (2.A.6) produces no greenhouse-gas emissions and is thus not a key category.

4.1.6.1 Source-category description (2.A.6)

Currently, the report tables list produced amounts of mixed asphalt products and NMVOC emissions.

In 2004, a total of about 52 million t of asphalt was produced in Germany, in a total of some 750 asphalt-mixing plants. Asphalt is used primarily in road construction, where it competes directly with concrete. In 1991, total production increased considerably; since 2000 it has been decreasing again.

Production statistics are collected by the German asphalt producers association (Deutscher Asphaltverband; DAV). A total of 60 % of all plants use heating oil EL as their main fuel – i.e. it is the fuel that causes the largest share of emissions. Some 25% of all plants use natural gas and some 15% use lignite dust. CO_2 is among the climate-relevant pollutants that are emitted. In addition, CO, NMVOC, NOx and SO_2 are also emitted, in considerably smaller amounts. CO_2 results from stoichiometric conversion of the fuels used: heating oil EL, lignite dust and natural gas.

4.1.6.2 Methodological issues (2.A.6)

No special calculation procedure is available for calculating fuel inputs in source category 1.A.2. Nonetheless, fuel inputs are taken into account via Energy Balance evaluation, and they are coupled with suitable emission factors.

Emission factors have been determined country-specifically, pursuant to Tier 2. For determination of emission factors for pollutants other than CO_2, emissions-measurements from over 400 asphalt-mixing plants, made during the period 1989 through 2000, were used. 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 for production (process emissions). CO occurs primarily in incomplete combustion processes. To date, NO_X, SO_2 and CO emissions are calculated solely in connection with fuel inputs.

Only emissions from asphalt production are reported. No figures are available for emissions released during laying of asphalt. The emission factors were determined country-specifically, via experts' assessment.

4.1.6.3 Uncertainties and time-series consistency (2.A.6)

As the extensive measurement data shows, 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.

4.1.6.4 Source-specific quality assurance / control and verification (2.A.6)

For reporting under CRF 2.A.6, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents.

The country-specific emission factor for NMVOC was subjected to specialised review, because the IPCC default value is considerably higher. It is true that organic additives are used in laying of asphalt, to enhance binding between different road layers. Nonetheless, the default factor of 320 kg/t asphalt given by the IPPC Guidelines is clearly too high. Asphalt contains only 5 % binding agents (bitumen). Only this substance can contribute to the pertinent NMVOC emissions. Further studies are needed in this area.

4.1.6.5 Source-specific recalculations (2.A.6)

No source-specific recalculations were required.

4.1.6.6 Planned improvements (source-specific) (2.A.6)

Careful review is to be carried out to determine whether any CO_2 emissions come from sources other than the fuels. Calculation of the emissions is expected to make it possible to assess this source category's relevance with regard to greenhouse-gas emissions.

In addition, review is to be carried out to determine the extent to which uncertainties can be estimated.

4.1.7 Mineral Products: Glass production (2.A.7)

CRF 2.A.7 Glas					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
	- / -	CO_2			

Gas	CO_2	CH_4	HFC	PFC	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)	CS	NO	NO	NO	NO	NO	CS	NO	NO	CS
EF uncertainties in %	NE									
Distribution of uncertainties	NE									
Method of EF determination	CS									

Source category 2.A.7 "Glass production" is not a key category.

The currently valid IPPC Good Practice Guidance contains no proposals or information relative to calculation of process-related CO_2 emissions for the glass industry. In keeping with the general recommendations of the IPPC Good Practice Guidance, therefore, a special method had to be developed. The following remarks present the status of the relevant discussion about methods.

4.1.7.1 Source-category description (2.A.7)

Germany's glass industry produces a wide range of different glass types that differ in their chemical compositions. Germany's glass sector comprises the following sub-sectors: container glass, flat glass, household and table glassware, special glass and mineral fibres (glass and rock wool). The largest production amounts, by percentage, are found in the sectors of container glass (about 57.4 % of total glass production in 2004) and flat glass (about 21 % of total glass production in 2004). Together, these sectors account for 78.4 % of total glass production.

A large number of primary and secondary raw materials are used. A distinction is made between natural raw materials, synthetic raw materials and the additives used in small amounts (refining agents, colouring agents and decolouring agents). The most important natural raw materials include sand, limestone, dolomite, feldspar and igneous rocks. The most important synthetic raw material used in production of high-volume glasses such as flat glass and concave glass is soda ash. Glass cullet (including cullet from within production operations and from outside sources) is an important secondary raw material. Input cullet amounts, with respect to total amounts of molten glass, are influenced by the glass-melting technology used, the required glass quality and the availability of cullet meeting the required quality requirements.

In glass production, glass batch mixtures, mixed homogeneously from primary and secondary raw materials, are placed into special melting ovens designed especially for the type of glass to be produced. Depending on the type of glass involved, oven design and desired melting speed, the mixture is melted down at temperatures between 1450°C and 1650°C. The chemical reactions and physical processes that then take place until workable glass is produced are extremely complex. The process-related CO_2 emissions under consideration here are released from the raw-material carbonates during the melting process in the oven. CO_2 emissions – in considerably smaller 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.

4.1.7.2 Methodological issues (2.A.7)

The CO_2 emissions (the main pollutant) are calculated via a Tier 2 method, because the activity rates 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 / sodium carbonate (Na_2CO_3), magnesium carbonate ($MgCO_3$) and barium carbonate ($BaCO_3$).

Measurements obtained from studies of exhaust-gas streams cannot be used for determination of the amounts of CO_2 emitted by the glass industry in Germany. One reason for this is that the exhaust gases that occur during the melting process are vented together with combustion-related exhaust gases, as a collective exhaust-gas stream. Therefore, a calculation procedure is used as an alternative to evaluation of such measurements. Such calculations require data on the amounts of glass produced in Germany, the relevant weight fractions of the glass oxides CaO, MgO, Na_2O and BaO in pertinent glass products, and the extent of use of cullet as a secondary raw material. Use of cullet, as a secondary raw material, has a direct impact on levels of process-related CO_2 emissions. Increasing the use of cullet as a component in the basic glass mixture reduces process-related CO_2 emissions. Data on cullet use in the container-glass sector is available from the association for glass recycling and waste avoidance (Gesellschaft für Glasrecycling und Abfallvermeidung; processed by BV Glas). No figures are available on cullet use in other glass-industry sub-sectors. At the same time, it is known that no cullet can be used in production of special and crystal glass (in some cases, not even cullet from within the same production operation can be used). For this reason, the applicable cullet percentage is considered to be 0% - with the exception of the cullet percentage for container glass. 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 (information sheet) 374 (ATV, 2004). These figures have been used to calculate emission factors for the following sub-sectors of the glass industry:

- Container glass
- Flat glass
- Household and table glassware (consisting of crystal and lead-crystal glass)
- Special glass (consisting of lamp glass, display screen glass, apparatus glass and optical glass)
- Glass fibre
- Rock wool

The production figures (activity rates) are taken from the regularly appearing annual reports of the national glass industry association (Bundesverband Glasindustrie; BV Glas, 2005). "Production" refers to weights of produced glass; these are considered to be equivalent to weights of melted glass and, thus, to weights of input raw materials. Further processing and treatment of glass and glass objects are not considered.

The following procedure was used to determine emission factors for the various glass oxides $EF_{x,i}$:

$$EF_{X,i} = [M_{CO2}] / [M_X]$$

where:

X	- Glass oxide
i	- Industry sector, type of glass
$E_{FX,i}$	- Emission factor for glass oxide X [t CO2 / t glass oxide X]
M_X	- Molecular weight of X [g/mol]
M_{CO2}	- Molecular weight of CO2 (= 44 g/mol)

Each glass oxide's share of the relevant glass' total glass-oxide content was determined. This weighting was then taken into account in determination of the emission factor $EF_{x,i}$ for the relevant glass type. To begin with, this emission factor refers to the amount of CO_2 that occurs in formation of all of the glass oxides contained in the glass (and given as [t CO_2/ $t_{glass\ oxides\ in\ glass\ i}$]). On the basis of the glass oxides' percentage shares [weight %] of the total glass composition of glass type i, the emission factor $EF_{x,i}$ was then set in relation to a tonne of molten glass i (given in [kg CO_2/ $t_{molten\ glass\ i}$]). A conversion factor = 1 was assumed in the calculations.

The amount of CO_2 released in production of glass type i (E_i) can then be determined as follows:

$$E_i = AR_i * EF_{x,i}$$

where:

E_i	- CO_2 emissions for production of glass type i
AR_i	- Activity rate / production rate for glass type i
$EF_{x,i}$	- Emission factor $EF_{x,i,}$ for glass type i

The following emission factors were calculated for the various industry sectors:

Table 42: Emission factors for various glass types (calculated in comparison with figures from the CORINAIR manual)

Glass type i	$EF_{i,M}$ [kg CO_2/ $t_{molten\ glass\ i}$] - calculated -	$EF_{i,M}$ [kg CO_2/ $t_{molten\ glass\ i}$] - from CORINAIR -
Container glass	193	171 - 229
Flat glass	208	210
Household and table glassware	120	-
Special glass	113	27 - 178
Glass fibres	198	0 - 470
Rock wool	299	238 - 527

Since data on cullet use for container glass is available, the emissions-relevant activity rates can be calculated directly in the CSE:

$$AR_{container\ glass} = PAR_{container\ glass} (1 - z)$$

where:

$AR_{container\ glass}$	-	Emissions-relevant activity rate for container glass
$PAR_{container\ glass}$	-	Activity rate for container glass (production amount)
Z	-	Cullet percentage in basic mixture

The following activity rates were determined for 2004:

Table 43: Activity rates for the various industry sectors

Industry sector	Activity rate 2004 [1,000s of t]
Container glass	4.105,0 (PAR)/ 361 (AR)
Flat glass	1.508,3
Special glass	366,0
Household and table glassware	327,9
Glass fibres and wool–	365,7
Rock wool	481,4

Source: BV Glas, 2005

4.1.7.3 Uncertainties and time-series consistency (2.A.7)

The production data has been taken from the internal statistics of the BV Glas glass-industry association. Since this association represents nearly all container-glass producers in Germany, the data for this industry sector is highly accurate. 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. The annual reports appear regularly, once per year. Until about 2002, BV Glas also compared the data with data of the Federal Statistical Office. Then, the official statistics were restructured in a manner that eliminated all time-series consistency. For this reason, as of 2002 the data comes only from internal surveys.

The applicable cullet percentage is considered to be 0% - with the exception of the cullet percentage for container glass. For this reason, it is possible that the emissions are being overestimated. In the case of container glass, it has been possible to take account of the cullet fraction only as of 1995 – the data for the period before that year remains to be determined. This inconsistency has a significant impact on the time series for all CO_2 emissions.

4.1.7.4 Source-specific quality assurance / control and verification (2.A.7)

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 this comparison, the calculated emission factors may be considered accurate.

The information regarding the chemical composition of the various relevant glass types is considered correct and properly reviewed, since it is based on the VDI 2578 guideline and is found in the BVT's information sheet (Merkblatt) about the best available technologies in the glass industry.

For reporting under CRF 2.A.7 Glass production, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents.

4.1.7.5 Source-specific recalculations (2.A.7)

Key recalculations were required as a result of introduction of the new calculation procedure. Slightly lower emissions were calculated for the base year than had been calculated in previous years, when use of cullet for container glass was not yet taken into account. An emissions reduction of up to 750 Gg CO_2 per year is seen as of 1995, primarily as a result of inclusion of cullet use for container-glass production.

4.1.7.6 Planned improvements (source-specific) (2.A.7)

In the interest of consistency in time series for the activity rates and emissions, the cullet fraction used in container-glass production prior to 1995 is to be determined via surveys or modelled.

Plans also call for determination of uncertainties.

4.1.8 Mineral Products: Ceramics (2.A.7)

CRF 2.A.7 Glas					
Key category by level (l) / trend (t)		Gas (key category)	1990 - contribution to total emissions	2004 - contribution to total emissions	Trend
	- / -	CO_2			

Gas	CO_2	CH_4	HFC	PFC	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)	D	NE	NO	NO	NO	NE	NE	NE	NE	NE
EF uncertainties in %	NE									
Distribution of uncertainties	NE									
Method of EF determination	D									

Source category 2.A.7 "Ceramics" is not a key category.

4.1.8.1 Source-category description (2.A.7)

The currently valid IPPC Good Practice Guidance contains no proposals or information relative to calculation of process-related CO_2 emissions for the ceramics industry. To date, relevant data has been entered into the inventory solely from the Federal Environmental Agency's research project "Limestone balance" ("Kalksteinbilanz")[21] .

At present, the only aspects of the ceramics industry being considered are the brick-industry sectors – specifically, the areas of masonry bricks and roof tiles.

The raw materials for bricks consist of various loams and clays, of varying composition. Raw meal also contains limestone, in varying amounts.

4.1.8.2 Methodological issues (2.A.7)

The CO_2 emissions (the main pollutant) are calculated via a Tier 1 method, because no detailed data is available and because this source category is not a key category.

Official statistics are of limited use in determining actual production trends in the brick industry, in terms of weights, since such statistics list masonry-brick production in cubic metres and roof tiles in numbers of tiles. For this reason, weight figures for production were determined on the basis of experience (of the National Association of the German brick industry – Bundesverband der Deutschen Ziegelindustrie).

To permit determination of a focused activity rate for limestone inputs, so-determined volume of masonry-brick and roof-tile production must be tied to a limestone-input factor. With information provided by the national brick-industry association (Bundesverband Ziegelindustrie) regarding limestone fractions in raw meal for brick production, it is currently estimated that each tonne of raw meal contains 65 kilograms of limestone. This factor is then applied, as is, to the relevant production amounts, and this yields the data shown below.

[21] In progress: the research project "Balancing of production and use of limestone, and listing of CO_2 emissions" ("Bilanzierung der Gewinnung und Verwendung von Kalkstein und Ausweisung der CO_2-Emissionen"), FKZ 20541217/02

Table 44: Estimated limestone amounts in brick production

Limestone production [kt]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Input for all brick types	1.028	1.099	1.171	1.242	1.313	1.384	1.271	1.292	1.281	1.264	1.190	1.002	914	911	929

Source: Calculations from the "limestone balance" project ("Kalksteinbilanz"; UBA 2006, FKZ 20541217/02)

These limestone amounts do not have to be checked against the limestone balance (see 4.1.3).

When the IPCC default emission factor is used, the following CO_2 emissions result:

Table 45: CO_2 emissions in brick production

[Gg]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
CO_2 emissions	490	525	562	598	634	670	624	632	631	628	598	508	464	462	475

Source: Calculations from the "limestone balance" project ("Kalksteinbilanz"; UBA 2006, FKZ 20541217/02)

4.1.8.3 Uncertainties and time-series consistency (2.A.7)

The uncertainty in the activity rate for limestone inputs is considered relatively large, due to the incompleteness of the available data. It is placed at +/-25 %. Under the assumption that complete limestone deacidification takes place, the emission factor used has no uncertainty.

Both the activity rate and the emission factor show time-series consistency.

4.1.8.4 Source-specific quality assurance / control and verification (2.A.7)

At present, verification can be carried out for only the production volumes determined for the brick industry. Such verification finds discrepancies between the calculations of the "limestone balance" project and the inventory activity rates for calculation of dust emissions. The activity rates for calculation of dust emissions are all higher. At the same time, in terms of trend they do agree with the calculations of the "limestone balance" project.

4.1.8.5 Source-specific recalculations (2.A.7)

The CO_2 emissions from the ceramics industry have been determined for the first time.

4.1.8.6 Planned improvements (source-specific) (2.A.7)

By the 2007 report, the calculations from the "limestone-balance" project will undergo specialised review, and the source category will be considered more comprehensively.

4.2 Chemical industry (2.B)

Source category 2.B is sub-divided into sub-categories 2.B.1 through 2.B.5. These include ammonia production (2.B.1), nitric acid production (2.B.2), adipic acid production (2.B.3) and carbide production (2.B.4).

In the CSE, sub-category Other (2.B.5) includes fertiliser and nitrous oxide production, organic products, soot and titanium-oxide production, sulphuric acid production and hydroxylamine production.

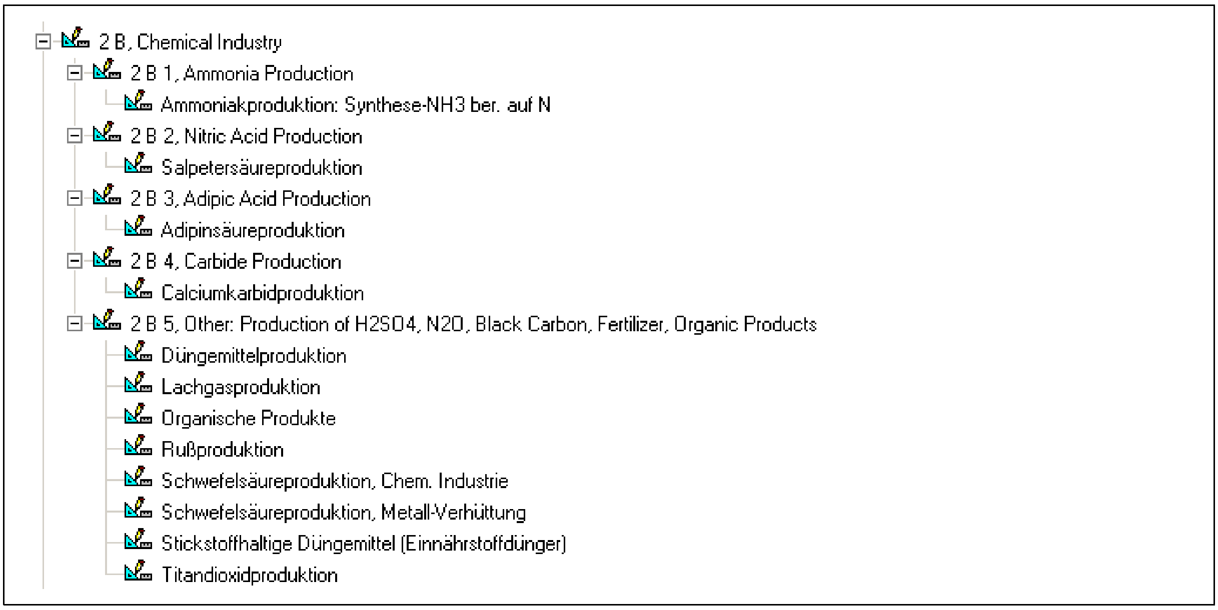


Figure 34: Structural allocation, 2.B Chemical industry

4.2.1 Chemical industry: Ammonia production (2.B.1)

4.2.1.1 Source-category description (2.B.1)

CRF 2.B.1					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
Ammonia Production	l / t	CO_2	0,36 %	0,49 %	rising

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	1,5	NO	NO	NO	NO	NO	CS	NO	NO	NO
EF uncertainties in %	50									
Distribution of uncertainties	N									
Method of EF determination	D									

The source category Ammonia production (2.B.1) is a key category for CO_2 in terms of emissions levels and trend.

Ammonia is produced on the basis of hydrogen and nitrogen, using the Haber-Bosch procedure. Hydrogen is obtained from synthetic gas. It is generated in a highly integrated procedure within a steam reforming process, generally on the basis of natural gas. Nitrogen is provided by the decomposition of air.

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 under mild conditions in a fired primary reformer and 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

Most plants operate according to the steam-reforming principle, with naphtha or natural gas. Only 3 % of European plants use the partial oxidation procedure.

The more than 15 % decrease in production (corresponding to an amount of about 400 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. The reasons for the re-increase as of 1995, to the 1990 level, are not understood; the re-increase may be due to a change in statistical survey methods, however. After 1990, production levels fluctuated only slightly. In 2003, production increased noticeably – by 9 % – over the previous year. In 2003, two nitric-acid producers entered the market. These additions are likely the result of the fact that ammonia is a precursor substance for nitric acid.

4.2.1.2 Methodological issues (2.B.1)

Carbon dioxide emissions are dependent upon the quantity and composition of the input materials. It can be assumed that all the carbon is converted into carbon dioxide and will be emitted into the air sooner or later.

In Germany, carbon dioxide is converted into urea at three production sites. At one site, part of the carbon dioxide is filled into bottles for selling. In all cases, however, subsequent emission of carbon dioxide into the air is inevitable.

At present, only two of five ammonia-production facilities in Germany use the partial oxidation process.

The emissions are calculated as follows:

Emission (kt) = Ammonia production quantity (kt) x emission factor (kt/kt)

Due to a lack of plant-specific data, an emission factor of 1500 kg CO_2 /t NH_3 – the proposed default factor – is used.

The amount of ammonia produced in Germany is determined by the Federal Statistical Office (DESTATIS, Fachserie (technical series) 4 Reihe 3.1, 1991-2004). Since the relevant figures are normed to nitrogen content, the above-mentioned emission factor has to be adjusted by a stoichiometric factor of (17/14).

The CSE thus uses an emission factor of 1815 kg CO_2 / t N for calculations.

Total production comprises "Ammonia, water-free" ("Ammoniak wasserfrei" (Melde Nr. (reporting number) 4142 00 until 1994 and, as of 1995, 2415 10 750), which is far and away the largest component, and "Ammonia in aqueous solution" ("Ammoniak in wässriger Lösung", Melde Nr. 4144 00 until 1994 and, as of 1995, 2415 10 770).

Natural gas is used both as a fuel and as a raw material. It remains to be determined what amount of natural gas Germany's energy balance includes under "non-energy-related consumption".

The emission factor for NO_X depends on the type of production in question. The Federal Environmental Agency's internal estimates are 1.1 kg NO_X/t NH_3, for partial oxidation, and 0.32 to 0.175 kg NO_X/t NH_3, for steam reforming (with the specific figure depending on what process variation is used). For purposes of emissions calculation, the average for all types of production is assumed to be decreasing over time – from 0.45 kg NO_X/t N in 1990 to only 0.3 kg NO_X/t N in 2010. The interim-year figures used for emissions calculation were interpolated.

4.2.1.3 Uncertainties and time-series consistency (2.B.1)

The CO_2 emission factor is only an average value that, given the various different production conditions involved, cannot fully and precisely reflect the actual situation.

The NO_X emission factor is also only an average value that, given the various different production conditions involved, cannot fully and precisely reflect the actual situation. This restriction applies all the more for the interpolated figures used for the interim years.

The small production share for "Ammonia in aqueous solution" is secret for several of the years in question. For 1999, this share was estimated on the basis of ratios in neighbouring years, taking the production amounts for "Ammonia, water-free" into account. Among the years 1990 to 1994, only 1993 has a non-secret production figure; this figure was not used for the 4 other years.

It is possible that a change in statistical survey methods, effected from 1994 to 1995, caused an apparent production increase of about 400 kt.

4.2.1.4 Source-specific quality assurance / control and verification (2.B.1)

For reporting, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents.

4.2.1.5 Source-specific recalculations (2.B.1)

Since the undocumented emission factor of 690 kg/t for carbon dioxide has been replaced with the default value, throughout the entire time series, recalculation is required. Such recalculation yields carbon dioxide emissions, throughout the entire time series, that are twice as high as the "old" emissions levels.

4.2.1.6 Planned improvements (source-specific) (2.B.1)

An ongoing research project of the University Utrecht, using the NEAT model (Non-energy Emission Accounting Tables; WEISS, PATEL, n.d.) is studying the extent to which CO_2 emissions occur during non-energy-related consumption during product use and within industrial processes. The project is expected to yield insights regarding how much natural gas for ammonia production the Federal Republic of Germany's energy balance includes under non-energy-related consumption.

Since there are only five ammonia manufacturers in Germany, an effort is being made to have the manufacturers report their carbon-dioxide and NO_X emissions directly.

4.2.2 Chemical industry: Nitric acid production (2.B.2)

4.2.2.1 Source-category description (2.B.2)

CRF 2.B.2					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
Nitric Acid Production	l / t	N_2O	0,37 %	0,72 %	rising

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	NO	NO	NO	NO	NO	5,5	CS	NO	NO	NO
EF uncertainties in %						50				
Distribution of uncertainties						N				
Method of EF determination						CS				

The source category "Nitric acid production" (2.B.2) is a key category in terms of both emissions level and trend.

In production of nitric acid, nitrous oxide occurs in a secondary reaction. In Germany, there are currently only six plants for the production of nitric acid.

HNO_3 production occurs in two process stages:

a) **Oxidation of NH3 to NO and**
b) **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 C. The related reaction, according to the Oswald 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.

4.2.2.2 Methodological issues (2.B 2)

The **activity data** is taken from the Federal Statistical Office (DESTATIS, Fachserie 4, Reihe 3.1: manufacturing sector, production within the manufacturing sector). In general, the cited figures for nitric-acid production are normed to N and are stoichiometrically converted (*63/14), by the Federal Environmental Agency, from N to HNO_3. Since no consistent time series are available, several adaptations had to be made:

Production figures are available for the old German Länder for 1990-1992 and for 1991-1992 for the new German Länder (Melde-Nr. (reporting number) 4123 10). The 1990 production figure for the new German Länder was not available and has been estimated.

Beginning in 1993, production figures are no longer listed separately for the new and old German Länder; for this reason, the 1993 and 1994 figures for the new and old German Länder were determined in keeping with the relevant regions' share of total production in 1992.

For 1995-2001, following conversion of federal statistics, the nitric-acid production figures of Melde-Nr. 2415 10 503, which are still normed to N, are used. Since 2002, the Federal Statistical Office no longer lists this position individually; instead, it lists as part of a sum under Melde-Nr. 2415 10 500 (nitric acid, nitrating acids). For estimation of the relevant share for nitric acid, this sum value is multiplied with nitric acid's share of this sum value in 2001 (0.693).

Due to production fluctuations, the activity-data trend is unstable and fluctuating. In 2003, production increased by nearly 2/3 over the 2002 level. Upon enquiry, the Federal Statistical Office attributed this extraordinarily large production increase to the appearance of two additional manufacturers. In 2004, significant growth of 14 % took place from this high level.

The existing data for N_2O is based on measurements. The **emissions** depend on the technological situation and operating conditions, vary extensively from one plant to another, and even vary within the same plant. A detailed consideration of the IPCC requirements relative to emissions calculation is provided in the Annex (Chapter 14.2.2.1.1).

Since 1990, the N_2O emission factor used has been consistently given as 5.5 kg N_2O/t HNO_3. In the underlying research project from 1993 (SCHÖN, WALTZ et al, 1993), it is assumed, however, that 283 kg NH_3/t HNO_3 are used for production of nitric acid, and that some 1.5 % of this ammonia are converted into N_2O. A check calculation using industry figures (3120 m^3 waste gas/t HNO_3 and 500-1000 ppm N_2O) confirmed the above emission factor, in terms of order of magnitude, by yielding 3.1-6.2 kg N_2O/t HNO_3.

NO_x emissions figures for the entire period are based on UBA-specific emission factors that have decreased strongly over time. This trend is based on a forecast for 2010 pursuant to which in that year the average specific emissions will be on the order of those of state-of-the-art plants in 1997 (0.75 kg/t).

At present, no emission factors from plant data are available.

As of 2010, old plants may no longer exceed the applicable emissions standard, from TA Luft 2002, of 800 mg N_2O/m^3. This announced N_2O emissions limitation will cause the EF for nitrous oxide to fall in future.

Table 46: N_2O and NO_x emission factors from nitric acid production

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
N_2O [kg/Mg]	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5
NO_X [kg/Mg]	7,9	6,6	5,0	3,7	3,0	2,5	2,1	1,8	1,6	1,5	1,4	1,35	1,29
Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
N_2O [kg/Mg]	5,5	5,5	5,5										
NO_X [kg/Mg]	1,24	1,19	1,13					0,75					

Table 47: N_2O and NO_x emissions from nitric acid production

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
N_2O [Gg]	15,1	12,0	11,0	11,0	11,1	12,7	12,1	12,1	12,0	12,5	13,4	11,8	12,9
NO_X [Gg]	21,7	14,3	10,1	7,3	6,1	5,8	4,6	4,0	3,5	3,4	3,4	2,9	3,0
Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
N_2O [Gg]	21,3	24,3											
NO_X [Gg]	4,8	5,2											

4.2.2.3 Uncertainties and time-series consistency (2.B.2)

The emissions-determination process normally requires not only the produced amount sold; it also requires the entire produced amount, including amounts directly processed further within the plant. On the basis of the supposition that a significant portion of production is not sold, it must be determined whether production statistics include produced amounts that do not enter the market. Furthermore, it must be verified whether the Federal Statistical Office takes all plants into account. The Federal Statistical Office's combined listing of nitric acid and nitrating acid as of 2002 should be reviewed.

4.2.2.4 Source-specific quality assurance / control and verification (2.B.2)

For reporting, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents.

4.2.2.5 Source-specific recalculations (2.B.2)

No source-specific recalculations were required.

4.2.2.6 Planned improvements (source-specific) (2.B.2)

Where no emissions measurements for specific plant types are available, but activity rates are available for emission factors, adequate country-specific emission factors should be derived on the basis of the default values from the IPCC guidelines. For derivation of emission factors, it is necessary to know whether the activity rates have the same degree of differentiation as the emission factors. Aggregations should be carried out only where detailed activity rates are lacking for the relevant individual types.

In 2010, all existing plants in Germany must meet the requirements of the Clean Air Directive (TA Luft 2002). The limit of 800 mg/m^3 for N_2O emissions can be met by installing a catalytic reducer. In this light, it will become possible to obtain more precise emission factors.

4.2.3 Chemical industry: Adipic acid production (2.B.3)

4.2.3.1 Source-category description (2.B.3)

CRF 2.B.3					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
Adipic acid production	l / t	N_2O	1,48 %	0,45 %	falling

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	NO	NO	NO	NO	NO	D, PS	NE	NE	NE	NO
EF uncertainties in %						+/- 10%				
Distribution of uncertainties						N				
Method of EF determination						CS				

Adipic acid production is a key category in terms of emissions level and trend.

The IPCC has not specified any methods for calculating N_2O emissions from adipic acid production. As the description below indicates, the manner in which the EF for N_2 has been determined is in keeping with the Tier 3 approach.

On an industrial scale, adipic acid is produced via oxidation of a mixture of cyclohexanol and cyclohexanone (ratio: 93/7). Pursuant to IPCC-GPG (2000: Tab. 3.7, note a), only one facility, a facility in Japan, is presumed to use pure cyclohexanol (EF there is 264 kg/t); at other facilities, production uses cyclohexanol with ketone, in various amounts, along with nitric acid. In this 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 patented, and put into operation, a system for thermal decomposition of nitrous oxide into nitrogen and oxygen. Decomposition takes place nearly completely. 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 96-98%. In March 2002, operations were begun with a plant, from another producer, that also uses thermal N_2O decomposition. Following initial technical problems, the system has been in constant operation since 2003. The overall fluctuations in decomposition rates – and, thus, the remaining emissions – are maintenance-related.

Production levels fluctuate from year to year, by up to one-fourth. Between 1990 and 2003, production grew by 2/3.

4.2.3.2 Methodological issues (2.B.3)

Until around the mid-1990s, producers provided data only on amounts produced. The IPCC default emission factors were used to calculate nitrous oxide emissions for this period. For the period following, in addition to reporting their production figures, producers also confidentially reported their N_2O emissions, along with necessary background information. This fact is highly significant with regard to the precision of the reported data; without data on technically unavoidable N_2O production, and – especially – without information as to the operating period of the relevant decomposition facilities, estimates of the reduction in nitrous oxide emissions would have been so imprecise that it would have been necessary to continue using the default EF.

The fluctuations in the emissions data are the result of disruptions of emissions-reduction systems (maintenance work, fire damage, other failure of system components).

The IPCC also lists default EF for NOx, NMVOC and CO. These values are questioned by one producer and cannot be quantified, since the relevant gas flow is combined with that from HNO_3 production. Since additional information is to be gathered in this regard, the default EF are currently not being used. This is all the more appropriate in that the IPCC Guidelines are being revised.

4.2.3.3 Uncertainties and time-series consistency (2.B.3)

The uncertainties in time-series consistency have been eliminated, since all manufacturers now provide the relevant data. Corresponding uncertainties result from the IPCC N_2O emission factor range of +/- 10 % that was used from 1990 until 1996 (in part). According to one producer, the uncertainties are no greater than +/- 5%.

4.2.3.4 Source-specific quality assurance / control and verification (2.B.3)

Information provided by producers enjoys 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 should also be noted, however, that the figures used are also provided to licensing authorities.

For reporting, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents.

4.2.3.5 Source-specific recalculations (2.B.3)

One producer's data that was lacking for the period since the producer's emissions-reduction facility was commissioned in 1994 has been provided, and relevant source-specific recalculations have been carried out as a result.

4.2.3.6 Planned improvements (source-specific) (2.B.3

Since all producers now provide the relevant data, no improvements are planned with regard to N_2O. Some useful information relative to calculation of NO_X, NMVOC and CO emissions is available from producers. Additional information is required, however.

4.2.4 Chemical industry: Carbide production (2.B.4)

4.2.4.1 Source-category description (2.B.4)

CRF 2.B.4					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
	- / -				

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor CaC_2	PS	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emission factor SiC	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
EF uncertainties in %	50									
Distribution of uncertainties	N									
Method of EF determination	PS									

The source category "Carbide production" (2.B.4) 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 the old German Länder. In the period under consideration until 2003, this producer cut his production by about half.

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.

4.2.4.2 Methodological issues (2.B.4)

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.

With covered ovens, producers collect all of the carbon monoxide produced in the process and recycle it for further use. Following such use for energy recovery – i.e. following its combustion to produce carbon dioxide – it serves as an auxiliary substance for production of lime nitrogen and secondary products. Reactions in these processes yield carbon dioxide in mineral form, as black chalk. In this form, it is used in agriculture.

As a result, production in the old German Länder achieves a substantially lower emission factor for carbon dioxide from calcium carbide production.

Upon request, the relevant producer provides the Federal Environmental Agency with data on the degree of reduction achieved – and, thus, on the emission factor involved – and on amounts produced. The total emissions are calculated as the product of activity rate and emission factor.

Since Germany has only one producer, the relevant data must be kept confidential. The only published data consists of that for amounts produced in the former GDR; this data was published, until 1989, by that country's central statistical authority. That data, together with existing estimates for 1991 and 1992, has been used to interpolate the production in the new German Länder for 1990.

4.2.4.3 Uncertainties and time-series consistency (2.B.4)

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. On the other hand, the assumed reduction rate of about 80% should probably be considered an average value for the time period in question, and the producer has already indicated that even higher reduction rates were achieved in recent years. Before making any use of such lower EF for recalculation, the Federal Environmental Agency will review the data in question, however.

4.2.4.4 Source-specific quality assurance / control and verification (2.B.4)

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.

For reporting, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents.

4.2.4.5 Source-specific recalculations (2.B.4)

No source-specific recalculations have been carried out to date. No revision of producers' figures is expected. Neither is any recalculation of the production figures for the three reference years in the new German Länder expected.

4.2.4.6 Planned improvements (source-specific) (2.B.4)

No improvements are planned at present.

4.2.5 Chemical industry – other: Emissions from other production processes (2.B.5)

4.2.5.1 Source-category description (2.B.5)

CRF 2.B.5					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
Other	l / t	CO_2	0,53 %	0,92 %	rising

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF) soot	CS	CS	NO	NO	NO	NO	NO	CS	NO	CS
Emission factor (EF) ethylene, styrene	NO	D	NO	NO	NO	NO	NO	NO	CS	NO
Emission factor (EF) methanol, 1.2-dichloroethane	CS	D	NO	NO	NO	NO	NO	NO	NO	NO
Emission factor (EF) transformation processes, coke burn-off in catalyst regeneration in refineries	CS	NO	NO	NO	NO	NO				
EF uncertainties in %										
Distribution of uncertainties										
Method of EF determination										

The source category "Other emissions from other production processes" (2.B.5) is not a key category.

A range of different chemical production processes are potential sources of CO_2, CH_4 and NMVOC emissions. These processes include production of soot, ethylene (ethene), ethylene dichloride (1,2-dichloroethane), styrene and methanol, along with transformation processes and coke burn-off in catalyst regeneration in refineries. CO_2 is released in combustion, while CH_4 can occur as a secondary product of industrial processes and then be emitted into the atmosphere. To date, the German greenhouse-gas inventory has not taken all such sources into account.

N_2O emissions from hydroxylamine production are reported in Chapter 4.2.6.

4.2.5.2 Methodological issues (2.B.5)

CO_2 emissions: In the 2006 - 2004 reporting year, CO_2 emissions into the atmosphere are now covered for the sources soot production, methanol production, transformation processes and coke burn-off in catalyst regeneration in refineries. The data has been collected recently, with the aim of ensuring coverage of all relevant emissions sources, since base-year emissions are being defined in this reporting period. Reviews to date indicate that other emissions sources from refineries (heavy-oil gasification, calcination and hydrogen production) are already covered as part of refineries' own consumption (cf. Chapter 3.1.2).

CH_4 emission factors: The international guidelines give very little attention to this source category. The IPCC Guidelines list as potential emissions sources – without any claim to completeness – production of soot, ethylene, dichloroethylene (presumably, 1,2-dichloroethane is meant; see the remark under footnote 22), styrene and methanol. The guidelines list emission factors for the processes that were identified in studies from 1987 and 1988: These IPCC default EF are listed in Table 48 below.

Table 48: IPCC default emission factors for CH_4 from other chemical industry processes

Soot	Styrene	Ethylene	1,2 - dichloroethane[22]	Methanol
[kg CH_4/t]				
11	4	1	0,4	2

The IPCC Good Practice Guidance does not discuss this subject further.

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.

In keeping with these technical standards, the three German producers of industrial soot report an emission factor of 0.027 kg methane per tonne of industrial soot. Since 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.

As to the other four products, the largest German producer reports that no further methane emissions occur in these areas, thanks to thermal post-combustion. This technology has been in service since the 1980s, and thus the pertinent emission factors can be applied to the entire time series.

Table 49: National emission factors for CH_4 from other chemical industry processes

Soot	Styrene	Ethylene	1,2 - dichloroethane[23]	Methanol
[kg CH_4/t]				
0,03	0	0	0	0

NMVOC, CO und SO_2 – emission factors: For pollutants other than the methane considered above, the emission factors listed in Table 50 were used for Germany.

[22] Remark: In this IPCC table (Workbook p. 2.22, Tab. 2-9 and Reference Manual p. 2.23, Tab. 2-10), dichloroethylene has been replaced with ethylene dichloride (1,2–dichloroethane). This seems appropriate, since the relevant subsequent tables (2-10 and 2-11) list only "1,2, dichloroethane" and since the source listed by the IPCC Reference Manual on p. 2.67, Stockton et al., p. 49, also speaks of the substance "ethylene dichloride".

[23] Remark: In this IPCC table (Workbook p. 2.22, Tab. 2-9 and Reference Manual p. 2.23, Tab. 2-10), dichloroethylene has been replaced with ethylene dichloride (1,2–dichloroethane). This seems appropriate, since the relevant subsequent tables (2-10 and 2-11) list only "1,2, dichloroethane" and since the source listed by the IPCC Reference Manual on p. 2.67, Stockton et al., p. 49, also speaks of the substance "ethylene dichloride".

Table 50: Emission factors used in Germany for other pollutants

	Soot [kg CO / t]	**Soot** **[kg SO_2/t]**[24]	**Ethylene** [kg NMVOC / t]	**1,2 - dichloroethane** [kg NMVOC / t]	**Polystyrene** [kg NMVOC / t]	**Styrene** [kg NMVOC / t]
1990	4,8 / 5	19,5 / [(25)]	0,035	0,015	0,27	0,02
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				

The EF figures for NMVOC – polystyrene – were taken from the European Commission (2005, BREF polymers, 2nd draft), while for other products figures of German producers were used (since 2000, these figures have been available as confidential data). The default factors were used until 1999. The EF figures for CO and SO_2 in soot production are based on assumptions of the responsible expert within the Federal Environmental Agency.

Activity rates: The production statistics of the Federal Statistical Office (DESTATIS) include the following products (Table 51):

Table 51: Reporting numbers (Meldenummern) from production statistics

Line	**Polystyrene**	**Methanol**	**1,2 - dichloroethane**	**Soot**	**Ethylene**	**Styrene**
until 1994	4414 42	4232 11	4228 22	4113 70	4221 11	4224 60
as of 1995	2416 20 350 und ...390	2414 22 100	2414 13 530	2413 11 300	2414 11 300	2414 12 500

Most of the following activity rates were taken from production statistics.

[24] Where two EF are listed, the second figure refers to the new German Länder.
[25] No EF is listed for the new German Länder, since these SO_2 emissions can be taken account of only as a lump sum.

Table 52: Activity rates of methanol, 1,2-dichloroethane, soot, ethylene and styrene [t]

Production		Methanol	1,2 - dichloroethane (Ethylene dichloride)	Soot	Ethylene	Styrene
Year	Area					
1990	**D**	**1266239**		**401365**	**3071829**	**1289781**
	ABL	751083	1504577	394365	3071829	1289781
	NBL	515156		7000		
1991	**D**	**1231541**		**381561**	**3059474**	**1208046**
	ABL	716385	1306091	379561	3059474	1208046
	NBL	515156		2000		
1992	**D**	**1290994**		**377384**	**3335942**	**1130836**
	ABL	768831	1512774	376384	3335942	1130836
	NBL	522163		1000		
1993	**D**	**1202189**	**1654694**	**334620**	**3904814**	**1041505**
1994	**D**	**1438327**	**1881032**	**299000**	**4182722**	**1150723**
1995	**D**	**1425795**	**1796930**	**330799**	**4163377**	**1080531**
1996	**D**	**1546958**	**1887791**	**315587**	**3814680**	**1151244**
1997	**D**	**1409850**	**2278858**	**337579**	**4186421**	**1099974**
1998	**D**	**1596258**	**2528542**	**343319**	**4269586**	**1182697**
1999	**D**	**1533113**	**2806415**	**338542**	**4894764**	**1096934**
2000	**D**	**1886429**	**2902378**	**345976**	**5119316**	**1089573**
2001	**D**	**1921680**	**2597093**	**348371**	**5005029**	**957750**
2002	**D**	**1843285**	**3188715**	**338592**	**4944099**	**960561**
2003	**D**	**2008075**	**3184280**	**348318**	**5258006**	**1226236**
2004	**D**	**1822267**	**3276355**	**339765**	**5290938**	**1668951**

D: Germany; ABL: Old German Länder; NBL: New German Länder (ABL/NBL only 1990-1992)

The figure for soot production in the new German Länder in 1990 was taken from the Statistical Yearbook (Statistisches Jahrbuch) for the Federal Republic of Germany (DESTATIS, 1992a: p. 234); the figures for 1991 and 1992 were estimated, due to confidentiality requirements. The other data for soot production, and for production of ethene, styrene, methanol and 1,2 dichloroethane as of 1990, were provided by the Federal Statistical Office (DESTATIS, Fachserie 4, Reihe 3.1, 1991-2004: manufacturing sector, production within the manufacturing sector).

The reasons for the production fluctuations during the period under consideration are unknown.

4.2.5.3 Uncertainties and time-series consistency (2.B.5)

The emission factors for ethylene, methanol, 1,2-dichloroethane and styrene are based on evaluations carried out by German producers. In the 1980s, thermal post-combustion was introduced on a large scale. As a result, emissions of organic substances from German plants are low enough to be neglected. The uncertainties cannot be estimated, however. The new emission factors are valid for the entire time series. Fluctuations in the activity rates have occurred over the period under consideration. The reasons for this are unknown. Since the amounts produced – apart from a few insignificant estimates – have come from a trustworthy source, the pertinent uncertainties may be considered small. Corrections to producers' figures might be made within a three-year period, however. In spite of the survey changes that have occurred within the period under consideration, the data is considered to be consistent.

4.2.5.4 Source-specific quality assurance / control and verification (2.B.5)

The following figures, from inventory reports of other countries, could provide information relative to the EF that should be used for Germany:

- Japan:
  From representative waste-gas measurements, EF were formed that, in some cases, are more than 30 to 80 times smaller than the IPCC defaults. This is due to reduction measures (methane recovery, flaring) that, presumably, have not yet been taken into account in the IPCC defaults.
- Portugal:
  This country's EF for soot production, which is 25 % below the IPCC default, was obtained from measurements made in 1990-94 at the country's sole producer.

No source-specific quality assurance / control and verification has been carried out to date.

4.2.5.5 Source-specific recalculations (2.B.5)

Since the default values for methane and NMVOC emissions from ethylene, methanol, 1,2-dichloroethane, styrene and soot production have been replaced with a country-specific EF, recalculation has been carried out for these source categories.

4.2.5.6 Planned improvements (source-specific) (2.B.5)

As to CO_2 emissions from refineries, further review is required to determine whether these emissions include emissions from heavy-oil gasification, calcination and hydrogen production related to refineries' own consumption.

4.2.6 Chemical industry – other: N_2O emissions from caprolactam production (2.B.5)

4.2.6.1 Source-category description (2.B.5)

CRF 2.B.5					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
	- / -				

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF) Caprolactam						CS				
EF uncertainties in %						±50%				
Distribution of uncertainties						N				
Method of EF determination						CS				

Source category Caprolactam (2.B.5 Other emissions) is not a key category for N_2O. The relevant emissions were determined via the Tier 2 method.

In caprolactam production, N_2O is released as a by-product (ULLMANN´S ENCYCLOPEDIA OF INDUSTRIAL CHEMISTRY, 2000, hydroxylamine, Chapter 4). Caprolactam is produced via conversion of ammonia into caprolactam, via nitrogen oxide, hydroxylamine and oxime.

The following processes are used for production of hydroxylamine:

- catalytic hydration of nitrates,
- the Raschig process,
- acidic splitting of nitroalkanes,

- production of crystalline salt, and
- catalytic hydration of nitrogen oxide.

The Raschig process and catalytic hydration of nitrogen oxide are the most important of the aforementioned processes (ULLMANN´S ENCYCLOPEDIA OF INDUSTRIAL CHEMISTRY, 2000, hydroxylamine, Chapter 4). Production of crystalline salt and acidic splitting of nitroalkanes play subordinate roles.

Large producers in Germany use catalytic hydration of nitrogen oxide. For this reason, the present considerations focus on this process. In catalytic hydration of nitrogen oxide, N_2O and other gases are produced as by-products (see 1 and 2). Via thermal treatment, the pertinent exhaust gases, including N_2O, can be prevented from escaping (ULLMANN´S ENCYCLOPEDIA OF INDUSTRIAL CHEMISTRY, 2000, hydroxylamine, Chapter 4). It is not known whether such reduction processes are used in Germany. For this reason, a "worst-case scenario" is assumed. The resulting N_2O emissions are calculated from the pertinent stoichiometry and from the results of an applicable research project ("methods update for emissions calculation 2003 – sub-task the N_2O applications solvents and other product use – N_2O application CRF 3.D" ("Methodenaktualisierung für die Emissionsberechnung 2003 – Teilaufgabe: N_2O-Anwendungen Lösemittel und andere Produktverwendung – N_2O-Anwendung CRF 3.D").

4.2.6.2 Methodological issues (2.B.5)

In the following section, N_2O emissions from caprolactam production are estimated on the basis of suitable chemical reaction equations. A total of 98 % of the hydroxylamine produced worldwide is used for production of caprolactam (FALBE & REGITZ, 2005, page 1904). For derivation of the applicable amount of hydroxylamine produced, it is assumed that this percentage (98 %) also applies for Germany.

Caprolactam production is complex, consisting of several process steps in which N_2O is released via undesired secondary reactions. To determine N_2O emissions levels for hydroxylamine production, it is assumed here that caprolactam production takes place solely via cyclohexanonoxime, for the production of which hydroxylamine is used.

1st Process step

Hydroxylamine production begins with oxidation of ammonia, with oxygen, to form nitrogen oxide and water.

$$4\ NH_3 + 5\ O_2 \rightarrow 4\ NO + 6\ H_2O$$

Equation 1: Catalytic hydration of nitrogen oxide

It is assumed that 1.5 % of the ammonia reacts, in a secondary reaction, to form N_2O and water (see Methodological issues (2.B 2)).

$$4\ NH_3 + 4\ O_2 \rightarrow 2\ N_2O + 6\ H_2O$$

Equation 2: Catalytic secondary reaction – formation of N_2O

2nd Process step

In the next step, nitrogen oxide is reduced with hydrogen, sulphurous acid or electrical current. The yield for this is about 90 % (WIKIPEDIA, 2005).

$$2\ NO + 3\ H_2 \rightarrow 2\ NH_2OH$$

The input substances that do not react to form hydroxylamine (NH_2OH) – i.e. the remaining 10 % – can react to form N_2O and water. Since these substances are of value and can be recycled back to hydroxylamine production, it is assumed here that, via technical optimisation, the input substances can largely be prevented from reacting to form N_2O. The amount of NO that reacts further to form N_2O is thus estimated as 2 % of the aforementioned 10 %, i.e. 0.2 % of the NO educt used. Experts consider it unlikely that the actual value is any larger.

$$2\ NO + H_2 \rightarrow N_2O + H_2O$$

Equation 3: Secondary reaction in hydroxilamine production

3rd Process step

With the help of carbonyl compounds, hydroxylamine is used to produce cyclohexanonoximes; under Beckmann rearrangement, these react with H_2SO_4 to form caprolactam (WEISSERMEL & ARPE, 1998, page 276) (see Figure 35).

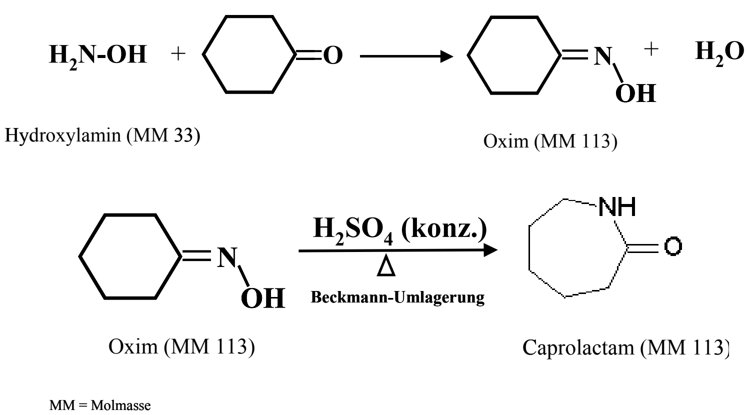


Figure 35: Caprolactam production from hydroxylamine, via Beckmann rearrangement

The emission factor determined from the relevant process steps is 3.63 kgN_2O / t caprolactam. This value is assumed to be constant over time.

Under the assumption that the efficiency of Beckmann rearrangement is already technically advanced and optimised in caprolactam production, the molar weight relationships between cyclohexanonoxime and caprolactam point to an input amount of 254,000 t/a of cyclohexanonoxim (in 2000) (see Table 53:). Here, it is assumed that the hydroxylamine used in Germany has been produced in Germany, and that 98 % of it is used for caprolactam production. For this reason, the hydroxylamine production volume can be estimated sufficiently well from the caprolactam production volume. The caprolactam production volume in the Federal Republic of Germany is shown in Table 53:. The annual production volumes for the years 1995, 1998, 2000, 2001 and 2002 are listed in AKTRIN TEXTILE INFORMATION CENTER (2005). To obtain needed figures not provided by this source, estimates were made via logarithmic interpolation between 1995 and 2002, as well as by extrapolation using the same trend line. As to the values for 2003 and 2004, constancy is assumed, on the basis of experts' estimates. The so-calculated / so-estimated values are shown in Table 53: in *italics*.

For the years prior to 1990, and most recently for 1988, the Federal Environmental Agency has access to figures for caprolactam production in the former GDR (1989 Statistical Yearbook / Statistisches Jahrbuch 1989 der DDR, 1989). These figures show a clearly increasing trend for the period 1985 to 1988. As a result, it is safe to assume that production in 1990 was of the same order as that of 1988 (79,025 t). In light of the fact that the GDR's production figures did not enter into emissions determination for the base year (1990) (Table 53:), it may be concluded that the listed value considerably underestimates the real emissions and thus must be considered very conservative in the framework of base-year-emissions determination.

Table 53: Time-series trend for caprolactam production volumes

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Caprolactam [1000 t/a]	*205*	*209*	*213*	*217*	*222*	200	*230*	*234*	260	*242*	254	264	264	*264*	*264*

Numbers in italics: interpolated and extrapolated values

Source: AKTRIN TEXTILE INFORMATION CENTER, 2005

Application of the above-described reactions and assumptions yields the following time-series trend for N_2O emissions:

Table 54: Time-series trend for N_2O emissions in connection with caprolactam production

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
N_2O [t]	745	759	774	788	806	726	835	850	944	879	923	959	959	959	959

4.2.6.3 Uncertainties and time-series consistency (2.B.5)

Several assumptions were made in determination of caprolactam production volumes.

Among these, the assumption regarding the emissions share (2%) has a significant impact on the amount of N_2O in question. For this reason, for uncertainty determination this assumption is considered especially carefully, and its impact on N_2O emissions is calculated. On the basis of a pertinent experts' assessment, it is assumed that the emissions share is of the same order as the above-assumed 2 %. Since experts consider an emissions share of over 3 % to be unrealistic, a maximum emissions share of 3 % is selected for uncertainty determination. According to experts, it is technically impractical to capture all of the nitrous oxide involved. For this reason 1 % is assumed as the minimum emissions share. Consequently, the resulting emissions can change by 1 %. This leads to an uncertainty of ±50 % in each case (i.e. U_{min}=-50 %; U_{max}=+50 %) throughout the entire period (1990-2004).

4.2.6.4 Source-specific quality assurance / control and verification (2.B.5)

For reporting, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents. The data for this source category was collected by an external expert, on behalf of the Federal Environmental Agency. Quality control was carried out by the external expert. Verification has not yet been carried out.

4.2.6.5 Source-specific recalculations (2.B.5)

No source-specific recalculations were carried out, since this source category is a new addition.

4.2.6.6 Planned improvements (source-specific) (2.B.5)

The amounts of caprolactam produced annually in Germany are very small in comparison to the amounts of products resulting from other relevant industrial processes, such as adipic acid and nitric acid. As a result, the amounts of nitrous oxide emissions that occur are so small that this process may be neglected as a source of nitrous oxide emissions for Germany. Consequently, no improvements are planned with regard to nitrous oxide emissions.

4.3 Metal production (2.C)

Source category 2.C is sub-divided into sub-categories 2.C.1 through 2.C.5. In the CSE, sub-category Iron and steel production (2.C.1) includes iron and steel production and tempered castings, pig-iron production, sinter production and steel products. Production of ferroalloys (2.C.2) is listed directly as such in the CSE. 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.5) is not further sub-divided. In the CSE, sub-category Other (2.C.5) includes lead production, thermal galvanisation, copper production and zinc production.

Figure 36: Structural allocation, 2.C Metal production

4.3.1 Metal production: Iron and steel production (2.C.1)

In previous reporting, total CO_2 emissions of the iron and steel industry (as currently identified) have been reported in Sector 1.A.2 and, as top-gas use, under 1.A.1.a and 1.A.1.c. Since the existing approach does not conform to the IPCC Guidelines, however, as of 2006 process-related emissions – initially, for CO_2 – will be reported under 2.C.1, in keeping with the requirements of the IPCC Guidelines (Reference Manual, 1996b: p. 2.26 ff) and the IPCC Good Practice Guidance (2000: p. 3.25 ff). As a result, in future it will also be necessary to check the sectors 1.A.2.a and 2.C.1 against each other – i.e. the CO_2

emissions then reported as process-related emissions, in 2.C.1, will have to be calculated out of those in 1.A.2.a, in order to prevent double-counting.

The CH_4 emissions are based on older Federal Environmental Agency estimates and will have to be verified in coming report cycles (2007).

4.3.1.1 Source-category description (2.C.1)

CRF 2.C.1					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
Steel (integrated production)	l / t	CO_2	3,87 %	4,04 %	rising

Gas	CO_2	CH_4	HFC	PFC	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)	CS	CS	NO	NO	NO	NO	CS	CS	CS	CS
EF uncertainties in %	-	-	-	-	-	-				
Distribution of uncertainties	-	-	-	-	-	-				
Method of EF determination	T2	-	-	-	-	-				

In light of its emissions levels and trend, the source category "Iron and steel production" is a key category.

In 2004, a total of 32.1 million t of raw steel, from ore, was produced in Germany in six integrated steel works. Electric steel production in 2004 amounted to 14.2 million t.

4.3.1.2 Methodological issues (2.C.1)

This sector comprises process-related CO_2 emissions from oxygen-steel works (blown steel) and electric-steel works.

Energy-related emissions are reported under 1.A.2. The method for determining energy-related and process-related emissions is described in the Annex, Chapter 14.2.3.1.

The emission factor for blown steel, for process-related CO_2 from reducing agents, takes account of process-related emissions from blast furnaces. Process-related CO_2 emissions from limestone use in pig-iron production are determined separately and reported together with emissions from oxygen-steel works (blown steel).

The other structural elements listed (foundries: iron and steel casting (including malleable casting); steel production: Siemens-Martin steel production: steel production: Thomas-steel production; steel production: rolled-steel production; steel-pig-iron production) are used for calculation of other pollutant emissions.

CO_2 emissions from reducing agents are determined in keeping with Tier 2 of the IPPC Guidelines.

In oxygen-steel works, the carbon dissolved in pig iron is driven out through the blowing process. Consequently, the emissions released during the blowing process do not have to be reported separately – all of the carbon in the reducing agents used in steel production is released into the atmosphere. The CO_2 emissions from electric steel production are added to process-related emissions; they are obtained by multiplying the standard emission factor for electrode combustion with the relevant amount of electrode burn-off.

4.3.1.3 Uncertainties and time-series consistency (2.C.1)

The time series is consistent, since the data is collected on a plant-specific basis and since it has been compiled according to the same method for all years concerned. The uncertainties are ± 5 %, since they result only from inaccuracies in measurement and analysis.

4.3.1.4 Source-specific quality assurance / control and verification (2.C.1)

For reporting, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents.

4.3.1.5 Source-specific recalculations (2.C.1)

In the CSE, a general change has been made in determination of emissions in source categories 2.C.1 and 1.A.2a.

Cross-checks between the sectors 1.A.2.a and 2.C.1 have been carried out.

4.3.1.6 Planned improvements (source-specific) (2.C.1)

Plans call for determination of the precise amounts of electrode burn-off involved. Calculations from the "limestone-balance" project will undergo specialised review by the 2007 report.

4.3.2 Metal production: Ferroalloys production (2.C.2)

Currently, three producers in Germany produce ferroalloys. Due to reasons of secrecy, only estimates are available for the relevant activity rates. It is assumed that as of 1993 no further ferroalloy production took place in the new German Länder. In addition, it is assumed that as of 1995 ferroalloys were produced solely via the electric arc process. It is also assumed that the blast-furnace process was used until 1995. The emission factors for the various processes were determined in the research project "New CO_2" ("Neu-CO_2") (FKZ 203 41 253/02).

4.3.2.1 Source-category description (2.C.2)

4.3.2.2 Methodological issues (2.C.2)

4.3.2.3 Uncertainties and time-series consistency (2.C.2)

4.3.2.4 Source-specific quality assurance / control and verification (2.C.2)

4.3.2.5 Source-specific recalculations (2.C.2)

4.3.2.6 Planned improvements (source-specific) (2.C.2)

Plans call for verification of the estimated values.

4.3.3 Metal production: Primary aluminium production (2.C.3)

4.3.3.1 Source-category description (2.C.3)

CRF 2.C.3					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
Aluminium production	- / t	PFC	0,20 %	0,04 %	falling

Gas	CO_2	CH_4	HFC	PFC	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)	CS	NE	NO	CS	NO	NO	NE	CS	NO	CS
EF uncertainties in %	15			15						
Distribution of uncertainties	N			N						
Method of EF determination	T3			T3						

In terms of its trend, primary aluminium production (2.C.3) is a key category.

In Germany, aluminium is produced at five 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 hall roofs. The principal climate-relevant pollutants emitted are CO, CO_2, SO_2, CF_4 and C_2F_6.

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. In this area, PFCs are produced in the production process as secondary products of electrolytic reduction of aluminium oxide (from alum earth) to aluminium. Thanks to extensive modernisation measures in German aluminium foundries, and to decommissioning of production capacities, absolute emissions from this sector fell by 71 % between 1995 and 2004. As to the future development of PFC emissions, stagnation at a low level can be expected.

4.3.3.2 Methodological issues (2.C.3)

The production figures for the year 2004 were taken from the monitoring report by the aluminium industry for the year 2004. The average anode consumption is 430 kg of petrol coke per tonne of aluminium. Table 55 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 hall 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 that can be used to calculate an SO_2 emission factor. The CO_2 emission factor is calculated on the basis of the specific CO_2 emissions for petrol coke, 101 t/TJ, as shown in Table 96. Through multiplication of the average anode consumption with the mean energy content and specific CO_2 emissions of petrol coke, a CO_2 emission factor of 1367 kg/t aluminium results. Theoretically, the CO_2 emission factor must be reduced by the proportion resulting from a CO component 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 55 were compared with the emission data in Best Available Technology (BAT) data sheets and other sources (such as VDI Guideline 2286 sheet 1).

Table 55: Activity rates and process-related emission factors for primary aluminium production in 2004

		Emission factors						
	Production [t]	**CO_2 [kg/t]**	**CF_4 [kg/t]**	**C_2F_6 [kg/t]**	**NO_X [kg/t]**	**SO_2 [kg/t]**	**C total [kg/t]**	**CO [kg/t]**
Primary aluminium	668834	1367	0,09	0,009	k.A.	6,02	k.A.	180

Emission data is available for PFC emissions from primary aluminium foundries, 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 is not published, but it is made available to the Federal Environmental Agency.

The measurements conducted in all German foundries in the years 1996 and 2001 form the basis for calculation of CF_4 emissions. In this context, specific CF_4 emission factors per anode effect[26] were calculated, in keeping with the technology used. The number of anode effects is recorded and documented in the foundries. The total CF_4 emissions in 2004 were calculated by multiplying the total anode effects by the specific CF_4 emissions per anode effect determined in 2004. The total emission factor for CF_4 is obtained by adding the CF_4 emissions of the five foundries and then dividing the sum by the total aluminium production of the foundries. C_2F_6 and CF_4 occur in a constant ratio of about 1:10. The above-described method was applied to the entire time series, and emissions for the years 1990 to 1996 were filled in via recalculations.

4.3.3.3 Uncertainties and time-series consistency (2.C.3)

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, in the framework of voluntary commitments no survey of the plant-specific number of anode effects in 1991, 1992, 1993 and 1995 was conducted, and no calculation was carried out for these years (cf. 4.3.3.6).

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.

4.3.3.4 Source-specific quality assurance / control and verification (2.C.3)

The industry conducts annual surveys of activity data and reports this data to (inter alia) the Federal Statistical Office and the Federal Office of Economics and Export Control. The

26 "...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)

relevant time series seems plausible and shows no inconsistencies. It is assumed that collection of this data is subject to quality assurance measures.

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 2004, the German emission factor for CF_4, resulting from anode effects, was 0.090 kg/t aluminium. This factor is slightly below the average international factor, as reported by the International Aluminium Institute (IAI), of 0.11 kg/t for point-feeder systems. The emission factor thus has been verified.

Measures for standardisation of QC/QA are currently being prepared.

4.3.3.5 Source-specific recalculations (2.C.3)

For the years 1990, 1994 and 1996, PFC emissions from the primary aluminium industry were determined via the described method (Tier 3b). In the process, recalculation was carried out for these years on the basis of the specific CF_4 emission factors per anode effect measured in 1996, as well as of the relevant numbers of anode effects, determined in each case on a plant-specific basis. In 2000, determination via recalculation was carried out on the basis of measurements made in 2001. Recalculation for 1991, 1992 and 1993 was carried out on the basis of the specific CF_4 emissions in 1990; for 1995, it was carried out on the basis of specific CF_4 emissions in 1994. For these recalculations, no surveys of operators were carried out with regard to plant-specific numbers of anode effects in these years. On the other hand, the aluminium industry's specific situation between 1991 and 1994, as described in Chapter 4.3.3.3, was taken into account in determination of the implied emission factors. The relevant values were suitably adjusted

As described in 4.3.3.2, the Federal Environmental Agency has received measurement data, from the aluminium industry, for 1997, 1998 and 1999.

4.3.3.6 Planned improvements (source-specific) (2.C.3)

The gaps in the time series were closed as described in 4.3.3.5. Uncertainties determination is to be carried out with the involvement of the industry association.

4.3.4 Metal production: SF_6 used in aluminium and magnesium foundries (2.C.4)

4.3.4.1 Source-category description (2.C.4)

CRF 2.C.4					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
SF_6 used in aluminium and magnesium foundries	- / t	SF_6	0,01 %	0,16 %	rising

Gas	CO_2	CH_4	HFC	PFC	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)	NO	NO	NO	NO	D	NO	NO	NO	NO	NO
EF uncertainties in %					-					
Distribution of uncertainties					-					
Method of EF determination					D					

All remarks in this chapter refer to emissions data for the 2004 report year; the emissions data on which these remarks is based is available as necessary in Germany.

In terms of trend, use of SF_6 in aluminium and magnesium production is a key category. Aluminium and magnesium production accounted for about 36% of SF_6 emissions in the year 2004.

Aluminium production: Prior to casting of molten aluminium, the inert gases nitrogen and/or argon are introduced to remove (degas) hydrogen, as well as alkaline and alkaline earth metals and solids; this prevents porosity in cast pieces. Halogens (chlorine, fluorine, etc.) are introduced for cleansing purposes. 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 in a few – usually smaller – secondary aluminium foundries and in laboratories. A review of the market for SF_6 in aluminium production revealed that such purification systems were last used in 1999 (no sales have occurred in Germany since 2000). In isolated cases, pure SF_6 has been used as a purification gas since 1999, however. Consumption of pure SF_6 has increased steadily since then.

Magnesium production: In magnesium casting, SF_6 is used as a protective gas over molten magnesium to prevent its oxidation and ignition. SF_6 has been used in this application since the mid-1970s. Use of this gas has competed with use of SO_2. Because SF_6 is easier to handle than the highly toxic SO_2, it became widely used in many new foundries. Since 2003, HFC-134a has been used, on a trial basis, instead of SF_6 or other protective gases. The amounts used in 2004 were still very small, however. In Germany, protective gas is only used for the processing of magnesium that has been imported in ingot form.

4.3.4.2 Methodological issues (2.C.4)

Aluminium production: All of the SF_6 used in Germany to purify molten aluminium is emitted completely upon use (consumption = emission; EF = 1). The practice of assuming the equivalence between consumption (AR) and emissions conforms to the IPCC method (IPCC, 1996a: 2.34).

SF_6 consumption was determined via direct surveys, regarding sales, of the few providers of the SF_6-containing gas mixture. The survey for the report year 2000 revealed that the gas mixture has no longer been sold since 2000.

For the report year 2002, a first survey of gas providers' SF_6 sales figures was carried out, and these figures were compared with data obtained from a first survey of amounts consumed by industry. This made it possible to identify SF_6 users, in the area of aluminium casting, who use pure SF_6. Since 2002, annual surveys have been conducted of sales figures relative to the application "aluminium casting".

Magnesium production: The quantity of SF_6 used for magnesium-cast production (consumption = AR) is equated with emissions, in accordance with the revised IPCC Guidelines (IPPC, 1996a: 2.34). SF_6 consumption is determined via direct surveys of foundries aimed at determining annual consumption levels. This is a feasible approach, since there are not a great many foundries. The usage data obtained is cross-checked against gas sellers' sales figures for this sector (these figures are also obtained via surveys).

The method outlined was applied for the report years 1995, 1997, 1998, 2000, 2001, 2002, 2003 and 2004. The missing annual data has been obtained by means of interpolation.

The emission factors listed in the CRF tables, up to the report year 2002, are obtained, via recalculation, from metal-production figures and the determined emissions (= consumption). The factors have not been used for emissions calculations. As of report year 2003, the "amount of SF_6 used" will be given as the activity rate, instead of the amount of Mg produced ("mg production") . Since emissions are calculated on the basis of this AR, 100% emissions (see above) yields an IEF of 1000 kg/t.

Table 56 contains an overview of the current status of data reporting (reporting year 2004). For the report years 1995 to 2000, certain other factors apply in some cases.

Table 56: Overview of data reporting and emission factors used in TABLE 2(II)s1, C. Metal production

	Data reported 2004	Substance	EF
SF_6 in aluminium production	yes	SF_6	1 (100%)
SF_6 in magnesium foundries	yes	SF_6	1 (100%)

4.3.4.3 Uncertainties and time-series consistency (2.C.4)

Studies have shown that part of the SF_6 – for example, that in Mg production – is broken down. For this reason, the assumption that amounts used are emitted to a degree of 100% (EF=1) probably overstates the emissions. Without more precise measurements that would make it possible to determine an average degree of decomposition in the process, the uncertainties cannot be quantified.

What is more, the uncertainties for the emissions result directly from the uncertainties for the identified usage amounts. The usage amounts determined for Mg foundries are considered sufficiently precise, since they were obtained via direct surveys of purchasing data. The usage amounts determined via the two different procedures (foundries, gas sellers; see above) show good agreement. The relevant uncertainties cannot be quantified.

In 2004, figures for sales of SF_6 to Al foundries were retroactively reviewed. This has made it possible to recalculate the time series for SF_6 emissions from aluminium production. The data now available is considered to be of good quality. The relevant uncertainty cannot be quantified.

4.3.4.4 Source-specific quality assurance / control and verification (2.C.4)

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. As to amounts consumed by Al foundries, for the 2002 report year, sales figures were compared for the first time with amounts used by industry, and this comparison revealed a discrepancy. This led to identification of a new source (aluminium casting, see above). For report year 2004, sales figures were again compared with the amounts used by industry.

The data for the 2004 report year, like the data for most of the previous years, was collected by an external expert working under commission to the Federal Environmental Agency. For the most part, quality assurance was carried out by an external expert. In addition, where possible, the data is checked by the relevant Federal Environmental Agency specialist upon receipt.

For reporting, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents.

4.3.4.5 Source-specific recalculations (2.C.4)

No recalculations have been carried out to date, although recalculations are required for the source SF_6 from aluminium production for report years prior to 2002. Recalculation is planned for the NIR 2007.

4.3.4.6 Planned improvements (source-specific) (2.C.4)

There are plans to review the market development of SF_6 in aluminium production regularly over the next few years. Such review will include gas sellers and users of SF_6. Plans also call for reaching agreements with users on regular data provision. This has not yet been accomplished.

There are also plans to work with magnesium users, and relevant system providers, in implementing out future options and improvements for collection of data on SF_6 and 134a.

As of 2007, surveys of SF_6 sales figures will be carried out in keeping with the Environmental Statistics Act (UstatG). Suitable survey parameters are currently being prepared by the Federal Environmental Agency and the Federal Statistical Office, in co-operation with gas sellers and the producer.

4.3.5 Metal production: Other (2.C.5)

Emissions from this source category are currently not being reported.

4.4 Other production (2.D.)

In the CSE, process-related emissions from production of particle board, and from pulp processing, are reported under 2.D.1 Pulp and paper.

Process-related emissions from production of alcoholic beverages, and from production of bread and other foods, are listed under 2.D.2 Food and drink.

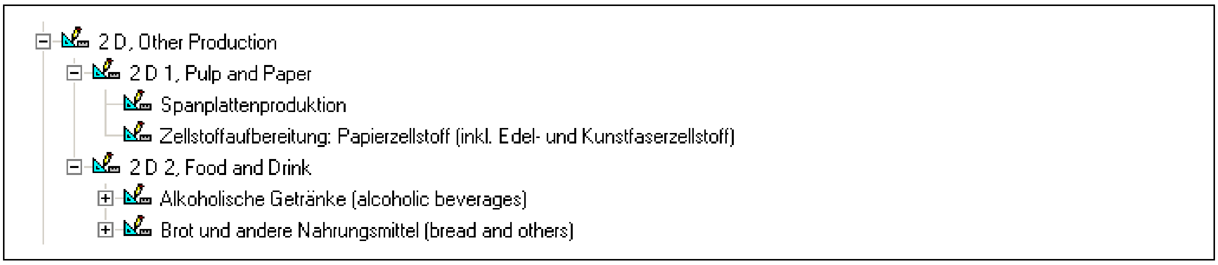


Figure 37: Structural allocation, 2.D Other production

4.4.1 Other production: Pulp and paper (2.D.1)

4.4.1.1 Source-category description (2.D.1)

CRF 2.D.1					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
	- / -				

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	NO	NO	NO	NO	NO	NO	D	D	D	D
EF uncertainties in %										
Distribution of uncertainties										
Method of EF determination										

The source category "Other production" (2.D.1) is not a key category with regard to production of pulp and paper (pulp and paper industry).

All emissions of climate-relevant gases from the pulp and paper industry in Germany result from combustion of fuels; for this reason, they are reported in Chapter 3.1 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 Guidelines* (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.

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 lime ovens.

A total of nine plants produce wood pulp.

A detailed description of the relevant processes – in the present example, fibre production (including wood-pulp production) and paper and carton production – as well as supplementary information about auxiliary boilers, is provided in Annex 2, Chapter 14.2.4.1.

4.4.1.2 Methodological issues (2.D.1)

The pulp, paper and printing industry produces no process-related emissions of climate-relevant gases within the meaning of the *IPCC Good Practice Guidance* (IPCC, 2000). For other gases, the IPCC-Guidelines emission factors listed in Table 57 were used.

Table 57: IPCC default emission factors for SO_2, NO_x CO, NMVOC from wood 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

In 2004, the following amounts were produced, in a total of 124 plants (Verband Deutscher Papierfabriken, Leistungsbericht (production report) 2005):

Production of paper, cardboard and carton (PCC): 20,392 million tonnes

Raw-material production:

Paper pulp		1,098,216 t
of this, sulfite pulp	616,639 t	
of this, sulfate pulp	481,577 t	
Wood pulp		1,395,514 t
Recycled paper (from 13,219,000 t of used paper)		11,545,000 t

These figures can be traced to the base year, 1990.

4.4.1.3 Uncertainties and time-series consistency (2.D.1)

The IPCC default values (IPCC, 1996b) were used for emissions calculation. These values were confirmed via consultation with German plant operators.

4.4.1.4 Source-specific quality assurance / control and verification (2.D.1)

For reporting, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents.

4.4.1.5 Source-specific recalculations (2.D.1)

NO_X, SO_2, NMVOC and CO emissions are being reported for the first time. The time series in the CSE have been adjusted, and the emissions back to 1990 have been recalculated.

4.4.1.6 Planned improvements (source-specific) (2.D.1)

Since plant operators have confirmed the emission factors from the international guidelines, no further inventory improvements for this source category are planned at present.

The "limestone balance" ("Kalksteinbilanz") R&D project (FKZ 205 41 217) is not covering caustification in sulphate pulp production, because such production is not relevant with regard to the limestone balance and since pertinent limestone use does not produce CO_2 emissions.

The CO_2 emissions from caustification in sulphate pulp production are of biogenic origin; thus, they do not have to be reported. In future, CO_2 of biogenic origin may be reported in the interest of enhancing transparency. If that were done, the biogenic CO_2 emissions would have to be broken down by energy-related and process-related emissions, for all relevant sectors, however.

4.4.2 Other production: Food and drink (2.D.2)

4.4.2.1 Source-category description (2.D.2)

CRF 2.D.2					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
	- / -				

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	IE	NO	NO	NO	NO	NO	NO	NO	CS / IPCC	NO
EF uncertainties in %									10 - 20	
Distribution of uncertainties									N	
Method of EF determination									CS	

The source category "Other production: food and drink" (2.D.2) is not a key category.

The food and beverage industry's emissions of directly acting 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) (IPPC Guidelines Handbook; 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 (IPPC, 1996a: p. 2.41). No emissions of nitrogen oxides (NO_X), carbon monoxide (CO) and sulphur dioxide (SO_2) occur.

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.

With revenue of about EUR 130.2 billion, the food and beverage industry was one of the most important industries in Germany in 2004. Nation-wide, some 5,970 industry companies employed about 520,000 people (BVE 2005). Pursuant to the 1993 Classification of Economic Activities (WZ 93), the food and beverage industry is divided into nine groups and a total of 33 classes. Governmental statistical evaluations are oriented to this classification. The German food industry includes an especially large number of small and medium-sized enterprises (SMEs); nearly 80 percent of its companies have fewer than 100 employees, and only 3 percent have more than 500 employees (BpB 2002, p.51).

Pursuant to the IPCC, emissions reporting for the food and drink source category covers the following products:

<u>Alcoholic beverages</u>

- Wine
- Beer
- Spirits

<u>Bread and others</u>

- Meat, fish and poultry
- Sugar
- Margarine and solid cooking fats

- Cake, biscuits and breakfast cereals
- Bread
- Animal feed
- Coffee roasting

Emission factors for NMVOC emissions relative to these products are listed (IPPC Guidelines Handbook, 1996c: S. 2.41f):

4.4.2.2 Methodological issues (2.D.2)

Data is collected, and calculations carried out, relative to the indirect greenhouse gases involved. For emissions calculation, the emission factors recommended by the IPCC or CORINAIR were used, except where national emission factors were available.

The Central System of Emissions (CSE) lists activity rates (produced amounts) and emission factors for NMVOC emissions for the relevant sectors. The activity rates for the relevant products / product groups have been taken from DESTATIS, with the exception of that for feedstuffs. The activity rate for feedstuffs has been taken from the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV).

In 2004, the relevant activity rates and emission factors were as follows:

Wine:
Activity rate:
6,034,000 hl white wine and must and
3,972,000 hl red wine and must (DESTATIS 2004 a);
total of 10,006,000 hl.
The activity rate for other wines (sparkling wine, apple wine, other fruit wines, etc.) was 431,000 hl.
Emission factors:
The following emission factors (EF) were used in emissions calculation:
EF (white wine) = 0.035 kg/hl,
EF (red wine)= 0.081 kg/hl,
EF (other wines) = 0.035 kg/hl.

Beer:
Activity rate:
97,748,000 hl (DESTATIS, Statistisches Jahrbuch (Statistical Yearbook), Fachserie 4, Reihe 3.1, No. 1596 10 000).
Emission factor:
0.02 kg/hl.

Spirits:
Activity rate:
4,286,000hl (DESTATIS, Fachserie 4, Reihe 3.1).
In the "spirits" category, brandy, whisky, rum and taffia, gin and geneva, vodka, fruit brandy, and liqueurs were included.
Emission factors:
Emissions were calculated in keeping with EMEP/CORINAIR 2000, with the emission factors EF (whisky)=15 kg/hl, EF (brandy)= 3.5 kg/hl, EF (other spirits)= 0.4 kg/hl.

Sugar:
Activity rate:
4,587,808 t (DESTATIS Fachserie 4, Reihe 3.1).
Emission factor:
1 kg/t.

Bread:
Activity rate:
3,895,673 t (DESTATIS Fachserie 4, Reihe 3.1).

Emission factor:
3.0 kg/t.
The emissions calculation method used previously was modified. Previously, emissions were calculated by multiplying the per-capita wheat-flour and rye-flour consumption by the total population. To permit differentiation between the two categories "bread" and "cake, cookies and breakfast cereals", the following DESTATIS data (Fachserie 4,Reihe 3.1) was used to determine the activity rate: No. 1581 11 000: Fresh bread, rolls, etc, without any added honey, eggs, cheese and fruit, 1582 11 300: crispbread and 1582 11 500: zwieback, toasted bread, etc., and other toasted goods.

<u>Cake, cookies and breakfast cereals</u>

Activity rate:
1,519,728 t (DESTATIS Fachserie 4, Reihe 3.1).
A range of different DESTATIS data was used for calculation of the activity rate; dry baked goods, fine baked goods, cereals, other processed grains and grain sprouts, and food preparations made from grain and grain products were included.
Emission factor:
3.0 kg/t.

<u>Meat, poultry and fish</u>

Activity rate:
2,106,327 t processed meat and poultry, 28,048 t fish (including 26,193 t smoked fish) (DESTATIS, Fachserie 4, Reihe 3.1)
Emission factor:
The emission factor for meat and fish processing is 0.3 kg/t; for the smoking process, 1.1 kg/t.

<u>Margarine and hard and hardened fats</u>

Activity rate
533,363 t, the total amount consists of 500,169 t of plant fats and 33,194 t of animals fats (DESTATIS, Fachserie 4, Reihe 3.1).
Emission factor:
1.0 kg/t.

<u>Animal feedstuffs</u>

Activity rate:
273,000 t (BMVEL, 2004).
Production of dry green fodder and fish meal was included. Animal fats, and animal and meat bonemeal were not included, since these products have not been fed to animals since 2001. Feedstuffs from food processing, such as molasses (from sugar production), by-products of breweries and distilleries were not included here, in order to prevent double-counting. The relevant product-specific emissions have been calculated elsewhere, in connection with the relevant products.
Emission factor:
1 kg/t.

The emissions are calculated pursuant to the IPCC Workbook (1996a: p. 2.81); this means that the activity rates are multiplied by emission factors.

For source category 2.D.2, this yields a total of 28.5 Gg NMVOC emissions (up from 25.5 Gg NMVOC in 2003).

4.4.2.3 Uncertainties and time-series consistency (2.D.2)

The uncertainties in the activity rates are estimated to amount to 10-20%. In the main, emission factors from the IPCC Guidelines for National Greenhouse Inventories: Workbook 2.41f and Emission Inventory Guidebook B 465, B 466 were used; these emission factors do not always conform to the circumstances prevailing in Germany. A research project for the UFOPLAN 2006 has been proposed that would improve the data and permit maximally realistic estimation of emissions from the food-industry sector (see the section "Planned improvements").

4.4.2.4 Source-specific quality assurance / control and verification (2.D.2)

Other countries' reports contain very little information about 2.D.2, and thus no comparisons are possible at present.

4.4.2.5 Source-specific recalculations (2.D.2)

Source-specific recalculations were carried out in the category of "bread", since the previously used calculation method was modified. In addition, recalculations were required for the following categories that were included for the first time this year: cake, cookies and breakfast cereals, meat, poultry and fish, margarine and hard and hardened fats, animal feedstuffs, coffee roasting, spirits. They were also required as a result of the distinction, made for the first time this year, between white wine and red wine.

4.4.2.6 Planned improvements (source-specific) (2.D.2)

The Federal Environmental Agency has proposed a research project for the UFOPLAN 2006, aimed at improving determination of process-related emissions from the food industry.

4.5 Production of halocarbons and SF_6 (2.E)

CRF 2.E					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
Production of halocarbons and SF_6: fugitive emissions	- / t	HFC	0,34 %	0,05 %	falling

Gas	CO_2	CH_4	HFC	PFC	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)	NO	NO	0,003	NO	0,005	NO	NO	NO	NO	NO
EF uncertainties in %			-		-					
Distribution of uncertainties			-		-					
Method of EF determination			-		-					

All remarks in this chapter refer to emissions data for the 2004 report year; the emissions data on which these remarks is based is available as necessary in Germany.

In terms of levels of fugitive emissions, and of its trend, production of hydrofluorocarbons (HFCs) and SF_6 is a key category. In 2004, this source category accounted for 1% of HFC emissions and <10% of SF_6 emissions.

Source category 2.E is subdivided into the sub-categories 2.E.1 and 2.E.2. These cover the areas of by-product emissions (2.E.1) and production-related emissions (2.E.2), as the following figure shows.

Figure 38: Structural allocation for 2.E., Production of halocarbons and SF_6

Previously, it was not possible to provide an emission factor for the HFC substance category, since different EF were used for the two areas of by-product emissions and process-related emissions. As a result of conversions in the H-CFC-22 production process, an EF can be provided as of the 2003 reporting year. This emission factor amounts to about 0.3% for all three sources.

Table 58 contains an overview of the current status of data reporting (reporting year 2004).

Table 58: Overview of data reporting and emission factors used in TABLE 2(II)s1, E. (a) Production of halocarbons and SF_6

	Data reported 2004	Substance
1. By-product emissions		
Production of H-CFC-22	yes	HFC-23
Other	NO	
2. Production-related emissions	yes	HFC, SF_6

4.5.1 By-product emissions (2.E.1)

4.5.1.1 Source-category description (2.E.1)

HFC-23 is incurred as a by-product of manufactured H-CFC-22. According to the larger of the two producers in Germany, the amount in question is about 3% of the entire H-CFC-22 production; this amount is always incurred in synthesis and is not collected for further processing (for example, for production of refrigerants) or for decomposition for substance recovery. For technical reasons, it is impossible to prevent part of this amount from escaping into the atmosphere.

In 1994, in Frankfurt, a CFC-cracking plant went into operation that cracks, at high temperature, excess HFC-23 produced during production of H-CFC-22 and that recovers hydrofluoric acid; i.e. no emissions are produced. HFC-23 produced at the second German production facility is largely captured at the production system itself; the substance is then sold as a refrigerant or – following further distillative purification – as an etching gas for the semiconductor industry. For the past several years, the excess amount that cannot be sold has been delivered to the cracking facility in Frankfurt. Since 1995, emissions have been substantially reduced through this measure. At the same time, some of the substance is not collected, however; the second H-CFC-22 facility generates by-product emissions on a level now estimated by the operator as about 0.3 % of H-CFC-22 production (1 % in the 2001 report year). In 2003, a plasma burner was installed. This has led to a further emissions reduction.

4.5.1.2 Methodological issues (2.E.1)

For the 1995 to 2003 report years, emissions of the latter producer have been calculated (via mass balance) on the basis of the amount of H-CFC-22 produced, of annual measurements of HFC-23 concentrations in the facility's waste gas, of amounts of HFC-23 sold and of the amounts of HFC-23 delivered to the cracking facility; for the 1995 report year, emissions-reduction measures (cracking facility) have been taken into account, as of the middle of the year, for the first production facility. The producer has reported the relevant produced amounts of R 22, the amounts of HFC-23 sold and the amounts of HFC-23 managed as waste. The emission factor listed in the CRF tables has been obtained via recalculation from the production amount and the relevant emissions determined on the basis of the mass balance.

The IPCC default emission factor is not used, since emissions-reduction measures have been taken (cracking facility).

4.5.1.3 Uncertainties and time-series consistency (2.E.1)

The emissions calculation obtained via the aforementioned mass balance is considered to be very accurate. The relevant uncertainties cannot be quantified (pursuant to IPCC, the maximum emissions are 4 % of the amount produced).

In co-operation with the producer of R 22 (this applies only to the second production facility, since the first production facility, as described in 4.5.1.1 does not produce any emissions), continual efforts are being made to improve data quality (including the emission factor).

4.5.1.4 Source-specific quality assurance / control and verification (2.E.1)

For reporting, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents.

4.5.1.5 Source-specific recalculations (2.E.1)

In co-operation with the second producer, the data for the previous report years is being checked further for plausibility and improved as necessary. This can lead to recalculations.

4.5.1.6 Planned improvements (source-specific) (2.E.1)

No improvements are planned at present.

4.5.2 Production-related emissions (2.E.2)

4.5.2.1 Source-category description (2.E.2)

In Germany, only one company produces these gases; its HFC und SF_6 production takes place at two locations. Since 2001 (retroactively to the start of production), the company has been reporting both production and the associated gas losses occurring as emissions. Emissions trends are tied to trends in amounts produced. As the only HFC producer in Germany, and now the only producer of SF_6 in Europe, the company enjoys protected confidentiality. The data is reported to the Federal Environmental Agency, but only in a form aggregated with emissions from CRF source category 2.E.1.

While SF_6 and HFC-134a are produced in Germany, no complete synthesis of HFC-227ea takes place domestically. Part of the HFCs produced in Tarragona, Spain, undergo subsequent distillation to pharmaceutical purity in Germany (use in dosing aerosols). Some emissions also occur in this process, as a result of minor gas losses.

4.5.2.2 Methodological issues (2.E.2)

The producer reports emissions of 134a, 227ea and SF_6. From this data, and from production figures, implied rates (both groups of data are reported confidentially) of fugitive emissions can be calculated; this rate has proven to be relatively constant. The rate for SF_6, about 0.5%, is higher than that for production of HFC-134a (0.3%) and that for purification of HFC-227ea (0.3%).

4.5.2.3 Uncertainties and time-series consistency (2.E.2)

The production data (AR) is very reliable, since it consists of internal records of the firm of Solvay Fluor und Derivate GmbH.

The emissions are obtained via mass-balancing. The mass balance can be understood as the difference between production as derived from raw-material inputs and production as derived from the produced amounts actually placed in tanks.

The production figures on which the emissions calculation is based may be considered accurate.

4.5.2.4 Source-specific quality assurance / control and verification (2.E.2)

For reporting, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents.

4.5.2.5 Source-specific recalculations (2.E.2)

No recalculations have been carried out to date, but recalculations will become necessary, for report years until 2001, once the quantities actually produced in Germany have been determined.

4.5.2.6 Planned improvements (source-specific) (2.E.2)

No improvements are planned.

4.5.3 Other (2.E.3)

No other sources of greenhouse-gas emissions are known.

4.6 Consumption of halocarbons and SF_6 (2.F)

CRF 2.F					
Key category by level (l) / trend (t)		**Gas (key category)**	**1995 – contribution to total emissions**	**2004 – contribution to total emissions**	**Trend**
Consumption of Halocarbons and SF6	l / t	SF6	0.35 %	0.24 %	stagnating
Consumption of Halocarbons and SF6	l / t	HFC	0.00 %	0.79 %	rising

Schadstoff	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)			s. Text	s. Text	s. Text					
EF uncertainties in %			-	-	-					
Distribution of uncertainties			-	-	-					
Method of EF determination			s. Text	s. Text	s. Text					

All remarks in this chapter refer to emissions data for the 2004 report year; the emissions data on which these remarks is based is available as necessary in Germany.

Consumption of hydrofluorocarbons (HFCs) and SF_6 is a key category for HFCs and SF_6 in terms of emissions levels and trend.

Source category 2.F is divided into the sub-categories 2.F.1 through 2.F.8. These include refrigeration and air-conditioning systems (2.F.1), foam blowing (2.F.2), fire extinguishers (2.F.3), aerosols/metered dose inhalers (2.F.4), solvents (2.F.5), semiconductor manufacturing (2.F.6), electrical equipment (2.F.7) and others (2.F.8), as shown in the figure below.

- 2 F, Consumption of Halocarbons and SF6
  - 2 F 1, Refrigeration
    - 2 F 1 a, Domestic Refrigeration
    - 2 F 1 b, Commercial Refrigeration
    - 2 F 1 c, Transport Refrigeration
    - 2 F 1 d, Industrial Refrigeration
    - 2 F 1 e, Stationary Air-Conditioning
    - 2 F 1 f, Mobile Air-Conditioning
  - 2 F 2, Foam Blowing
    - 2 F 2 a, Hard Foam
    - 2 F 2 b, Soft Foam
  - 2 F 3, Fire Extinguishers
  - 2 F 4, Aerosols
    - 2 F 4a, Metered Dose Inhalers
    - 2 F 4b, General Aerosols
    - 2 F 4c, Novelty Sprays
  - 2 F 5, Solvents
  - 2 F 6, Semiconductors
  - 2 F 7, Electric Equipment
    - 2 F 7 a, Switchgear
    - 2 F 7 b, Oth. Electric Equipment
  - 2 F 8, Other
    - 2 F 8 a, Soundproof glazing
    - 2 F 8 b, Car tyres
    - 2 F 8 c, Sport shoes
    - 2 F 8 d, Tracer gas

Figure 39: Structural allocation, 2.F Consumption of Halocarbons and SF_6

Halocarbons and SF_6 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. It is thus neither possible nor useful to provide a mean emission factor. Most of the EF used are CS; although some are D or M.

The "current emissions (A)", as listed in Table 2(I)s2, consist of the quantities of HFCs, PFCs and SF_6 that, during a report year, slowly escape from "stocks" and that are emitted in production and waste management. On the other hand, the "stocks" – actually, the average quantities present in the report year in question (average annual stocks) – correspond to the potential emissions (P) listed in Table 2(II)s2. The "stocks" do not include quantities from storage only. These amounts vary widely, and thus neither is it possible to determine these quantities nor is it useful to work with an average value. For reasons of confidentiality, potential emissions for the sub- source categories "solvents" and "semiconductor manufacture" cannot be given. For open applications (aerosols / metered dose inhalers), annual emissions are equated with the quantities sold within the relevant 12-month period (100 % emissions in the relevant year of sales). As a result, this area has no "stocks" that increase annually. The potential emissions thus correspond approximately to the current emissions in the report year in question. In individual cases involving "open" applications, a situation can arise, as a result of the calculation method chosen and the difference in reference period, in which A>P and, thus, the relationship P/A < 1.

Table 59 contains an overview of the current status of data reporting (report year 2004). In contrast to the overview shown here, many areas of the pertinent complete report are divided into further sub-groups, and individual factors are provided for these sub-groups.

Table 59: Overview of data reporting and emission factors used in TABLE 2(II)s1, F. (a) Consumption of halocarbons and SF_6: in this case: consumption of halocarbons

	Reported data 2004	**Substance**	**EF production [-]**[27]	**EF use [-]**	**EF disposal [-]**
1. Refrigeration and air-conditioning systems (2.F.1) (Tier 2)					
Household refrigeration	yes (Tier 2a)	HFC	NA	0.003	0.3
Commercial refrigeration	yes (Tier 2a)	HFC, PFC	0.002	0.015-0.15	0.3-0.5
Transport refrigeration	yes (Tier 2a)	HFC	0.002-0.005	0.15-0.25	0.3
Industrial refrigeration	yes (Tier 2a)	HFC	0.0015	0.07	0.3
Stationary air-conditioning systems	yes (Tier 2a)	HFC	20 g/system	0.06	NO
Room air conditioners	yes (Tier 2a)	HFC	NA	0.025	NO
Mobile air-conditioning systems					
- trucks	yes (Tier 2a)	HFC	0.002	0.10-0.15	0.3
- cars	yes (Tier 2a)	HFC	2 g/system	0.1	0.3
- buses	yes (Tier 2a)	HFC	5 g/system	0.15	0.3
- ships	yes (Tier 2a)	HFC	0.01	0.05	0.3
- rail vehicles	yes (Tier 2a)	HFC	0.002	0.15-0.25	0.3
- land machines	yes (Tier 2a)	HFC	5 g/system	0.15-0.25	0.3
2. Foam production (2.F.2) (Tier 2)					
Hard foam with 134a	yes (Tier 2a)	HFC	NA	0.005	NO
Hard foam with 365mfc/134a	yes (Tier 2a)	HFC	0.15	0.01	NO
Integral foam	yes (Tier 2a)	HFC	1	NO	NO
PUR foam (134a)	yes (Tier 2a)	HFC	1.5 g/can	1	NO
PUR foam (152a)	yes (Tier 2a)	HFC	1.5 g/can	1	NO
XPS foam (134a)	yes (Tier 2a)	HFC	0.27	0.0066	NO
XPS foam (152a)	yes (Tier 2a)	HFC	1	NO	NO
Soft foam	NO	HFC			
3. Fire extinguishers (2.F.3)	**yes (CS)**	**HFC**	**0.001**	**0.014**	**.NO**
4. Aerosols/metered dose inhalers(2.F.4)					
Metered dose inhalers	yes (CS)	HFC	0.15 g/can (10ml)	1	NO
Other	yes (Equ. 3.35)	HFC	0.015	1	NO
5. Solvents (2.F.5)	yes (Equ. 3.36)	HFC	NA	1	NO
6. Semiconductor production (2.F.6)	**yes (Tier 2)**	**HFC, PFC, SF_6**	**NA**	**(CS)**	**NO**

Equ. = Equation; equation from the IPCC GPG (2000)

[27] Unitless, unless indicated otherwise

Table 60: Overview of data reporting and emission factors used in TABLE 2(II)s1, F. (a) Consumption of halocarbons and SF_6; here: consumption of SF_6

	Reported data 2004	Substance	EF production [-]	EF use [-][28]	EF disposal [-]
7. Electrical operating equipment (2.F.7)					
Switching equipment	yes [Tier 3a]	SF_6	0,02	0,001-0,01	0,02
Other	yes [CS]	SF_6	0,15-1	NO	NO
8. Other (2.F.8)					
Sports shoes	yes [Equ. 3.23]	SF_6	NA	NO	1
Car tyres	yes [Equ. 3.23]	SF_6	0,002	NO	1
Insulating glass panes	yes [Equ. 3.24ff]	SF_6	0,33	0,01	1
Tracer gas	yes [CS]	SF_6	NA	1	NO

Equ. = Equation; equation from the IPCC GPG (2000)

In 2005, the data for 1990 was confirmed in the research project "Emissions and forecast of emissions of HFCs, PFCs and SF_6 in Germany – current status and development of a system for relevant annual determinations" (FKZ 202 41 356). The recalculation showed higher emissions for HFCs and SF_6. A recalculation for the entire time series of fluorinated gases was begun, but has not yet been completed. The main focus was on the base year 1995.The changes in total emissions of the three F gases relative to the data reported in the NIR 2005 amounted to 10 % at most and are due to refined research for that year. The recalculation will be completed and the results fully documented in the NIR 2007.

4.6.1 Refrigeration and air-conditioning systems (2.F.1)

Since the early 1990s, companies have been using hydrofluorocarbons (HFCs) on an increasing scale, primarily as substitutes for ozone-depleting and climate-damaging CFCs and H-CFCs. HFC emissions have increased sharply since 1995.

Use of refrigerants in stationary and mobile cooling/refrigeration systems now accounts for 50 % of HFC emissions and is thus the primary source of such emissions. The entire source category 2.F.1 is divided into two sub- source categories: Refrigeration and stationary air-conditioning systems and mobile air-conditioning systems.

4.6.1.1 Refrigeration and stationary air-conditioning systems (2.F.1)

4.6.1.1.1 Source-category description (2.F.1)

This sector can be roughly divided into the sub-source categories household refrigeration, commercial refrigeration, transport refrigeration, industrial refrigeration and stationary air-conditioning systems (cf. Table 599). In 2004, stationary refrigeration and air-conditioning systems accounted for 24 % of HFC emissions.

By far the most important pure HFC refrigerants in Germany are HFC-134a and the mixtures 404A and 507, both of which consist primarily of 125 and 143a. Together, 134a and 404A/507 account for more than 90% of annual new consumption. Because 404A and 507 are nearly identical in composition, and because they are thus used in the same areas, it is impossible to separate these two refrigerant mixtures. The two mixtures are thus reported as "404A".

[28] Unitless, unless indicated otherwise

The time-series development (increase) is directly related to increased use of HFC as a substitute for CFC, in refrigeration, and to the resulting increasing potential and current emissions. The increase, which was initially sharp, has been slowing somewhat. Before a reliable interpretation of this development can be provided, the emissions of the coming years will have to be awaited.

Emissions from disposal occur at the earliest from 2003 onwards. The emission factor was increased retroactively from 0.25 to 0.3 and thus corresponds to the standard value given in the IPCC Guidelines of 1999.

4.6.1.1.2 Methodological issues (2.F.1)

The total emissions for each sub- source category, and for each refrigerant, consist of the sub-emissions in the areas of production, usage and disposal. Emissions in these areas are determined separately. Disposal emissions occurred for the first time in 2003.

For calculation of HFC emissions from the sub-categories of refrigeration and stationary air-conditioning systems, individual data is collected/estimated, or refrigerant models used, for each group in question. Table 61 provides an overview of the methods used.

Table 61: Overview of methods used for sub-categories pertaining to "refrigeration and stationary air-conditioning systems"

Sub-category	**Method**	
Household refrigeration		Detailed description of the methods used for the various sub-categories are provided in the Annex, Chapter 14.2.5.1
Commercial refrigeration	Refrigeration model for "commercial refrigeration systems""	
Transport refrigeration/refrigerated vehicles	Refrigeration model for "transport refrigeration systems""	
Industrial refrigeration	Refrigeration model for "industrial refrigeration systems""	
Stationary air-conditioning systems	Refrigeration model for "stationary air-conditioning systems"	
Room air conditioners	Refrigeration model for "room air-conditioners""	

The emission factors used are the result of surveys of experts. The emission factors for disposal correspond to the standard values in the IPPC Guidelines of 1999.

4.6.1.1.3 Uncertainties and time-series consistency (2.F.1)

The emission factors are subject to considerable uncertainties. The literature (cf. refrigeration models: Annex, Chapter 14.2.5.1) contains a broad range of emission factors for identical applications. This is only partly a consequence of technical changes in systems' air-tightness or a manifestation of national differences. For the most part, it reflects real uncertainty, since too few solid empirical studies of these factors have been carried out (one of these is a study of supermarket emissions in Germany; ILK Dresden, 1999).

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 is considered too imprecise. In order to improve the reliability of data provided, the data was compared with the sales data (substance-oriented) of the manufacturers.

Until the 2001 report year, Germany reported only aggregated emissions, covering all sub-source categories. Within the context of emissions surveys for the years 1999 to 2001, and the emissions survey for the 2002 report year, the emissions for the report years 1995 to 1998 were reviewed and updated on the basis of new findings on input quantities and emission factors. Such information is often available only after a considerable delay; initially, therefore, it must be estimated. All data is thus being improved on an ongoing basis. Work to systematically quantify the relevant uncertainty is planned for the 2005 report year.

4.6.1.1.4 Source-specific quality assurance / control and verification (2.F.1)

The data for the 2004 report year, like the data for most of the previous years, was collected by an external expert working in the framework of a research project under commission to the Federal Environmental Agency.
"Emissions and forecast of emissions of HFCs, PFCs and SF_6 in Germany – current status and development of a system for relevant annual determinations." FKZ 202 41 356, "Emissions, activity rates and emission factors for fluorinated greenhouse gases (F gases) in Germany for the years 1995-1998: Adaptation to requirements for international reporting, and implementation of the relevant data within the Central System of Emissions (CSE)" FKZ 20141261/01, and “Data on HFCs, PFCs and SF_6 for national emissions reporting under the Framework Convention on Climate Change for report years 2004 and 2005” FKZ 205 41 217/01.For the most part, quality assurance was carried out by the external expert. In addition, where possible, the data is checked by the relevant Federal Environmental Agency specialist upon receipt.

For reporting, general QC (Tier 1) has been carried out for the first time; this QC corresponds to the requirements of the QSE manual and the associated documentation. The collected data on the size of source-category-specific HFC stocks, on composition of these 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[29], production and sales figures[30], etc.) are consulted, and experts (users, refrigerant manufacturers, suppliers, etc.) are consulted to determine the sources' reliability.

4.6.1.1.5 Source-specific recalculations (2.F.1)

Due to the complexity of this area, and of the large number of facilities involved, constant efforts are made to improve the database (breakdown of types of refrigeration systems, of refrigerants and coolants, of numbers of facilities, etc.). The new findings obtained via annual data surveys are continually applied to emissions calculations. As a result, changes occur in emissions figures for previous report years. For the 2004 report year, extensive recalculation on the basis of the then latest knowledge was planned. This recalculation was, in part, postponed until 2006, as it was necessary to first eliminate technical problems with the CSE database. As regards emissions from refrigeration containers in service, changes arose for the refrigerant 404A in the years 2001 to 2003, owing to a misplaced decimal point.

4.6.1.1.6 Planned improvements (source-specific) (2.F 1)

In future, efforts will be made to improve data by means of prompt enquiries regarding consumption levels (repairs, refill quantities, etc.). Such information can then be compared with model data. In view of the large number of systems involved (several million), however, emissions data is likely to remain subject to uncertainties. Additional possibilities for collecting and improving data are currently being evaluated. This includes, inter alia, adaptation of surveys, pursuant to Art. 11 Environmental Statistics Act (UstatG), to reporting

[29] Surveys pursuant to Art. 11 of the Environmental Statistics Act (UstatG).
[30] Surveys pursuant to the Foreign Trade Statistics Act (AHStatGes) and production statistics.

requirements, and assessment of IT-based programmes for collecting data on refrigeration systems.

4.6.1.2 Mobile air-conditioning systems (2.F.1)

4.6.1.2.1 Source-category description (2.F.1)

"Mobile air-conditioning systems" comprises vehicle air-conditioning systems in passenger cars, trucks and commercial vehicles, buses, agricultural machinery, rail vehicles and ships. Among mobile air-conditioning systems, car systems predominate, accounting for 90 %. In 2004, mobile air-conditioning systems accounted for 31 % of total HFC emissions.

Since about 1993, hydrofluorocarbons (HFCs) have been used as ozone-neutral substitutes for CFCs and H-CFCs. R134a now accounts for nearly 100 % of the HFC coolant used in mobile air-conditioning systems. In conversion of old R12 air-conditioning systems, a drop-in coolant (mixture) was used instead of R134a in a small proportion of cases; this coolant itself consists of 88 % R134a.

The time series show a significant increase in emissions since 1995. In the area of mobile air-conditioning systems, this increase is directly related to increased use of air-conditioning systems in vehicles, the resulting increased use of HFC and the resulting increasing potential and current emissions.

Emissions from disposal occur at the earliest from 2002 onwards. The emission factor was increased from 0.25 to 0.3 and thus corresponds to the standard value given in the IPPC Guidelines of 1999.

4.6.1.2.2 Methodological issues (2.F.1)

The total emissions for vehicle air-conditioning systems, for each vehicle model and each refrigerant, comprise sub-emissions in the areas of production, usage and disposal. Emissions in these areas are determined separately.

The procedure for calculating HFC emissions (solely HFC-134a) from mobile air-conditioning systems is described in the Annex, Chapter 14.2.5.2.

Since the 2002 report year, less relevant sources (such as agricultural machinery) have been included for the first time. In another change, carried out for the first time in this report year, only ships sailing under German flags – rather than all German ships – have been taken into account. The resulting changes are marginal, however.

4.6.1.2.3 Uncertainties and time-series consistency (2.F.1)

The quality of data on emissions from mobile air-conditioning systems is quite good; in fact, it is better than that for refrigeration systems and air-conditioning systems.

As a general principle, the above statements on the stationary systems sector also apply here. However, annual levels of HFC consumption may be calculated fairly precisely from statistics that cover the bulk of this sector, including new car registrations, production quantities and imports and exports of cars. Thanks to annual determination of model-specific rates of air-conditioning installation, and of the relevant fill amounts, the AR are very precise. Only in the area of commercial vehicles is the data subject to major uncertainties.

The emission factors previously assumed have been confirmed via the results of an expert report by the Federal Environmental Agency (UBA) and an EU study on leakage rates from mobile air-conditioning systems (ÖKO-RECHERCHE / ECOFYS, 2003). Overall, the EF are considered to be good. For precise information on uncertainties, the reader is referred to the aforementioned study/report.

4.6.1.2.4 Source-specific quality assurance / control and verification (2.F.1)

The data for the 2004 report year, like the data for most of the previous years, was collected by an external expert working under commission to the Federal Environmental Agency (cf. Chapter 4.6.1.1.4). For the most part, quality assurance was carried out by an external expert. In addition, where possible, the data is checked by the relevant Federal Environmental Agency specialist upon receipt.

For reporting, general QC (Tier 1) has been carried out for the first time; this QC corresponds to the requirements of the QSE manual and the associated documentation. Since 1993, all data required for calculations (see above) has been collected on an ongoing basis and checked for plausibility; it is not yet subject to standardised quality assurance / control and verification, however.

4.6.1.2.5 Source-specific recalculations (2.F.1)

Only minor recalculations are required for this area. The required recalculations have to do with additional, rather insignificant, sources and with reorganisation of emissions allocation.

4.6.1.2.6 Planned improvements (source-specific) (2.F 1)

Discussion on additional options for improvement is just beginning. Because the relevant data is already very precise, this discussion does not have priority, however.

4.6.2 Foam blowing (2.F.2)

Since 1993, companies have used hydrofluorocarbons (HFCs) as substitutes for ozone-depleting, climate-harming CFCs and H-CFCs. HFC emissions have increased sharply since 1995.

Use of HFCs as blowing agents for foam production is another main source of HFC emissions today accounting for 33 % of such emissions. The entire area is divided into three sub-groups: PU foam products, PU installation foam and XPS hard foam.

4.6.2.1 PU foam products (2.F.2)

4.6.2.1.1 Source-category description (2.F.2)

The sub-category "PU foam products" accounted for 4 % of HFC emissions in 2004.

PU foam products are composed of soft foam, integral foam and hard foam. For soft foam, HFC is not required as a blowing agent. HFCs have been used as blowing agents for hard foams only since 1998. Between 1995 and 1997, HFCs were used only for integral foams.

The time series, which does not begin until after 1995, shows a small initial increase in emissions. Both of these factors – the time of commencement and the small initial increase – agree with the historical development of HFC use in this application area, an area which arose only slowly, as a result of the long period of utilisation of H-CFC.

In addition to the HFCs 134a and 152a, HFC-365mfc and HFC-245fa have been used as blowing agents since 2002 and 2004, respectively. HFC-245ca is not used in Germany. HFC-365mfc has very small use quantities and is therefore reported together with HFC-245fa.

According to our surveys in 2003, 20 t of emissions of these two substances must be allocated to the 2002 report year, 21.8 t of such emissions to the 2003 report year, and 170.4 t to the 2004 report year. Assuming a GWP_{100} of 890 for this substance, these levels correspond to emissions of 0.02 million t CO_2 equivalents in 2002, 0.02 million t CO_2 equivalents in 2003 and 0.15 million t CO_2 equivalents in 2004.

4.6.2.1.2 Methodological issues (2.F.2)

The emissions data consists of:

1. Production emissions for each product group
   (= $EF_{production}$ * new domestic consumption (AR)),
2. Use emissions for each product group
   (= EF_{use} * systems in service (AR)),
3. Disposal emissions (not relevant to data (NO)).

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 is based on the amounts of foam products used in Germany (sales in Germany) since the introduction of HFCs. The data on new domestic consumption and domestic sales of foam products is obtained annually, through surveys of producers, surveys of users, association information, etc.. The EF on which emissions data is based are shown in Table 59.

The emission factors used are largely in keeping with the IPCC's published default values (D). They have been checked with national experts, however, and adjusted in part. For example, the emission factor for manufacture of PU hard foam using 365mfc/245fa was increased from 10% to 15%, because more emission-intensive foams were produced in 2004.

4.6.2.1.3 Uncertainties and time-series consistency (2.F.2)

The emissions data for prior years is 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.

It is not possible to quantify the uncertainties for the EF and the AR. While the EF are considered sufficiently precise, the AR are subject to considerable uncertainties, due to the product diversity involved. Because use of HFCs is still limited, however, the market can still be studied well via surveys and estimates.

4.6.2.1.4 Source-specific quality assurance / control and verification (2.F.2)

The data for the 2004 report year, like the data for most of the previous years, was collected by an external expert working under commission to the Federal Environmental Agency (cf. Chapter 4.6.1.1.4). For the most part, quality assurance was carried out by an external expert. In addition, where possible, the data is checked by the relevant Federal Environmental Agency specialist upon receipt.

For reporting, general QC (Tier 1) has been carried out for the first time; this QC corresponds to the requirements of the QSE manual and the associated documentation.

4.6.2.1.5 Source-specific recalculations (2.F.2)

HFCs have only been in use since 1996, and thus only the data for the report years 1998 to 1996 is reviewed within the context of emissions surveys for the 2001 report year. The results have been entered into the CSE database.

4.6.2.1.6 Planned improvements (source-specific) (2.F.2)

New possibilities for data collection are currently being evaluated. A first assessment of these possibilities has shown that it may be possible to obtain the AR for "new domestic consumption" via the Environmental Statistics Act (UstatG). At present, it is unclear whether data obtained in this manner will be available on time for reporting and whether it will be possible to take account of all HFC users relative to PU-foam production. Furthermore, it has emerged that existing statistics cannot be used to survey imports and exports of foams – and, thus, to survey domestic sales – since these statistics do not differentiate between the various relevant blowing agents. An effort is being made to find other solutions in this area.

4.6.2.2 PUR foam (2.F.2)

4.6.2.2.1 Source-category description (2.F.2)

The sub-category "PUR foam" accounted for only 4 % of all HFC emissions in 2004.

–Polyurethane foam in can form is sold in can sizes of between 300 and 750 ml[170]. HFC and propane/butane are used in conjunction with dimethyl ether (DME) as propellants. In Germany and, generally, in central Europe, industry has reduced its HFC use. Increasingly, HFC-152a – which has a lower greenhouse gas potential – is being used instead of HFC-134a. In addition, per-can quantities of HFCs have been reduced by increasing proportions of flammable propellants.

The time series for this application begins before 1995, due to the early discontinuation of CFC use in this area, and it shows a decreasing emissions trend. This is due to continuous reduction of HFC quantities per can (through increased use of halogen-free propellants).

In 2004, the amount of HFCs used fell by 60% compared to the 2003 report year. The reason for this is the switch to flammable propellants.

4.6.2.2.2 Methodological issues (2.F.2)

In computational terms, an average can has a foam weight of 660 g, approximately 18 % of which is propellant. In 1997, propellants were mixtures of which approximately 40 % consisted of the highly flammable gases propane, butane, and dimethyl ether (DME), and approximately 60 % consisted of HFCs, which are low-flammable (152a) or non-flammable (134a). Proportions of HFCs in propellants have been decreasing since 1995: In 1995, the HFC component in a 660-g can weighed 84 grams, while in 1997 it weighed only 75 g. Today, cans often contain less than 50 g of HFCs. On the average for all cans (winter foams, pistol foams, etc.), each can contains nearly 40 g of HFCs.

When calculating emissions, it is assumed that cans are used promptly by the professional craftsmen or do-it-yourselfers who buy them. In conformance with the IPCC Guidelines (IPCC Reference Manual, 1996b: p. 2.52) the HFC emissions of year n are thus considered equal to the sales for year n.

The following data is obtained for calculation of emissions from use (surveys of experts and manufacturers):

1. Domestic can sales,
2. Average amount of HFC per can,
3. Contained fractions of the propellants 152a and 134a.

Along with usage emissions, filling losses from domestic production must also be considered, for the year in question n. For calculation of these losses, experts are surveyed regarding HFC consumption for production.

The EF on which the emissions data is based are listed in Table 59. The $EF_{production}$ was determined via surveys of experts and manufacturers. In keeping with the IPCC method (IPCC 1996b, 2.52), it is assumed that all HFCs used are emitted. 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 propellant. The bulk of this propellant eventually enters the atmosphere after a certain delay. The same also applies to the cans that, in Germany, are brought to the central recovery plant for PU foam cans. In contrast to the IPCC method, it is assumed that all emissions occur in the year of sale, since use and disposal occur promplty.

The consumption quantities are based on sales (cans) and on the average quantity of HFCs per can.

4.6.2.2.3 Uncertainties and time-series consistency (2.F.2)

In the NIR 2003, it was noted that manufacturers' figures on amounts of contained HFC tended to be considered low. In 2005, it was again impossible to verify the manufacturers' figures with any conclusiveness. New information from a Swiss producer and from a recycling company (for the years 2003 and earlier) did lead to changed assumptions and AR, however – also for earlier years.

4.6.2.2.4 Source-specific quality assurance / control and verification (2.F.2)

Cf. Chapter 4.6.2.1.4.

4.6.2.2.5 Source-specific recalculations (2.F.2)

In the 2001 report year, recalculations were carried out, on the basis of discussions with the "Working Group on Polyurethane Foams", concerning the quantities of HFCs in individual cans and the ratio between 152a and 134a in HFC composition. Due to existing uncertainties, recalculations may again be necessary in the next report year.

4.6.2.2.6 Planned improvements (source-specific) (2.F.2)

The procedure corresponds to the Tier 2 approach. Data is available for domestic production, exports and imports. Additional verification is needed solely with regard to the average HFC quantity. Co-operation with manufacturers has not been possible to date.

4.6.2.3 XPS hard foam (2.F.2)

4.6.2.3.1 Source-category description (2.F.2)

The sub-category "XPS hard foam" accounted for nearly 24 % of all HFC emissions in 2004.

For XPS boards, no consumption or emissions of HFCs occurred prior to 1999, since H-CFCs or CO_2 were still being used at that time.

As of 2000, some domestic producers switched to HFCs. Since 2001, 152a and 134a have been used as blowing agents, either alone or mixed together, in addition to CO_2.

The time series, which does not begin until after 1995, shows a considerable increase in emissions. Both factors – the time of commencement and the increase in emissions – agree with the historical development of HFC use in this application.

4.6.2.3.2 Methodological issues (2.F.2)

The total emissions from this area consist of:

1. Production emissions (= $EF_{production}$ * new domestic consumption (AR)),
2. Use emissions (= EF_{use} * systems in service (AR)),
3. Disposal emissions (not relevant to data (NO)).

The basic data for determining new domestic HFC consumption consists of the total volume of XPS insulation foam (in m^3) produced annually with the two HFCs in question (134a and 152a).

In the case of 134a, 3.2 kg are required for production of one cubic metre of XPS foam; in the case of 152a, 3.0 kg are required. From these figures, as well as from the total amounts of XPS in m^3 (see above) produced annually with HFCs, the relevant new HFC consumption can be calculated.

The amount of HFC lost in the first year following production (production emissions) is calculated from the $EF_{production}$ and the annual new domestic consumption. The EF on which the emissions data is based are listed in Table 59. The $EF_{production}$ for HFC-152a is practically 100% (=1); i.e. this is a case of direct, open application. With HFC-134a, only part of consumption is emitted upon blowing; most of the substance enters into the product. Empirically, $EF_{production}$ was found to be 30% in 2001, 27% in 2002, 26% in 2003 and 27% in 2004.. A total of 25% of domestic consumption is considered a desirable value. Collection and recovery trials have been conducted, but to date no relevant systems have been implemented, for both technical and economic reasons.

Use emissions are calculated from the average amount of HFCs in XPS insulating foams in domestic service. This amount increases annually through new addition of insulating boards containing 134a. Given a product lifetime of 50 years, removals from products in service do not yet play any significant role. New additions of HFC products do not correspond to the annual new consumption, less production emissions, since foreign trade has a considerable impact on potential new additions. For XPS products containing 134a, Germany is far and away a net exporter. The adjusted export rate [171] for domestic production amounted to 75% for the years under consideration. In other words, the new HFC additions to the HFCs in domestic service consist of only 25% (the complement of the export rate) of the HFC-134a contained in products, following the blowing process.

The mean amount of HFC in service for a given year n is half of the sum of the final amount for the previous year, n-1, and of the final amount for the current year, n.

All of the activity data were provided by the Fachvereinigung Polystyrol-Extruderschaumstoff e.V. (FPX), by Dow, the market leader and by the European Extruded Polystyrene Insulation Board Association (EXIBA). The data was compared with that of other manufacturers.

The $EF_{production}$ were reported by the industry association at both the German and European levels (FPX and EXIBA).

The spokesman for the FPX industry association estimated annual degassing from enclosed HFC-134a cell gas as amounting to less 1 % – 0.66 % ($EF_{production}$ = 0.0066) in 2002. This figure is based, inter alia, on an internal BASF study on the half lives of the cell gases CFC-12, H-CFC-142b, H-CFC-22, HFC 134a and HFC 152a (WEILBACHER 1987). The study found that 134a degases with about the same speed as H-CFC-142b, while H-CFC-22 and HFC-152 degas virtually immediately. Fugitive emissions from boards depend on board thickness, and they can be given only as average values, or as values for specific board thicknesses. In the case of 134a, the half-life for 70 mm boards is about 35 years. It increases exponentially with increasing thickness. The figure of 0.66 % refers to medium board thickness.

4.6.2.3.3 Uncertainties and time-series consistency (2.F.2)

It is not possible to quantify the uncertainties for the EF and the AR. Because it includes only a small number of manufacturers, the German XPS market is not complex. Since the EF and AR were prepared in co-operation with manufacturers, they are considered sufficiently precise.

Since 2001, the industry association has carried out research to determine production of XPS (AR) and consumption of the two HFCs 152a and 134a (AR). 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 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. For 2001 and 2002, the data for direct losses in use of 134a was based on measurements carried out by Dow Deutschland at its Rheinmünster plant. The rate of emissions from products in service (EF_{use}; 0.66%) lies within the range of customary estimates of 1%. But since results from a laboratory study yield a value of about 0.66%, this value will be used as long as no reliable measurements with insulating boards in actual service have been carried out; such measurements could be considered more conclusive than laboratory values.

Production emissions develop proportionally to the annual domestic HFC consumption.

The mean annual amount of HFC-134a in domestic service in XPS insulating boards was first determined in 2001. As expected, this figure increased sharply in the years up to and including 2004.

4.6.2.3.4 Source-specific quality assurance / control and verification (2.F.2)

Cf. Chapter 4.6.2.1.4.

4.6.2.3.5 Source-specific recalculations (2.F.2)

No recalculations have been carried out.

4.6.2.3.6 Geplante Verbesserungen (quellenspezifisch) (2.F.2)

The option of a monitoring system, with formalised data transmission, is currently being discussed with the manufacturers and industry associations. This process is just getting underway.

New possibilities for data collection are currently being evaluated. A first assessment of these possibilities has shown that it may be possible to obtain the AR for "new consumption" via the Environmental Statistics Act (UstatG). At present, it is still unclear whether the data obtained via this pathway will be available in time for reporting. And existing statistics cannot be used to survey imports and exports of foams – and, thus, to survey domestic sales – since these statistics do not differentiate between the various relevant blowing agents.

4.6.3 Fire extinguishers (2.F.3)

4.6.3.1 Source-category description (2.F.3)

The sub-category "fire extinguishers" accounted for nearly 0.02 % of all HFC emissions in 2004.

Halons, which were permitted as fire extinguishers until 1991, have since been largely replaced by ecologically sound substances. In interior room sprinkler systems, inert gases (nitrogen, argon) are normally used instead of halon 1301. Hand-held fire extinguishers that produce a targeted jet of extinguisher now contain powder, CO_2 or foam instead of halon 1211.

HFC-227ea, one of the of the substances proposed by the U.S. as halon substitutes (HFC-23 and 236fa, HFC-227ea, PFC-218 and PFC-3110), was licensed in Germany in 1997. It is sold under the commercial name "FM-200" – essentially, by one licensed company. A further HFC (HFC-23) was licensed in the year 2002 but has not been used to date. HFC 236fa, which has been certified since 2001 for use in Germany, is used only in the military sector.

The time series, which do not begin until after 1995, show increasing emissions; this is in agreement with increasing use of HFCs as fire extinguishing agents.

4.6.3.2 Methodological issues (2.F.3)

The emission figures for HFC 227ea are based on statistical surveys by one company, covering the aspects of input quantities, refill quantities, accidental releases, releases in case of a fire, and trial floodings in Germany (by analogy to Tier 2). As a result, the entire market is not covered, since there is another seller. This seller has a very small market share, however. This seller is taken into account via an addition to the emission figures of the market leader.

The figures for HFC-236fa are based on obligations, at set forth in certifications, to report to the certification authority.

The IEF_{use} for HFC-227ea is calculated from the emissions data for the year in question, the annual amounts used (AR) and the mean annual amount in service. The EF_{use} for HFC-236 is estimated to be the same. The calculated IEF produces a false picture, since releases are still taking place, on a considerable scale, via tests.

The $EF_{production}$ are based on experts' estimations.

4.6.3.3 Uncertainties and time-series consistency (2.F.3)

The data on HFC-227ea and HFC-236 is considered good and very good, respectively.

4.6.3.4 Source-specific quality assurance / control and verification (2.F.3)

Cf. Chapter 4.6.2.1.4.

4.6.3.5 Source-specific recalculations (2.F 3)

No recalculations have been carried out.

4.6.3.6 Planned improvements (source-specific) (2.F.3)

No improvements are required at present.

4.6.4 Aerosols / metered dose inhalers (2.F.4)

4.6.4.1 Metered dose inhalers (2.F.4)

4.6.4.1.1 Source-category description (2.F.4)

The sub-category "metered dose inhalers" accounted for nearly 3% of all HFC emissions in 2004.

In Germany, the first metered-dose inhaler containing the propellant 134a was introduced on the market in April 1996; it was followed by two more such inhalers in 1997 and 1998. Enough HFC-powered metered-dose inhalers are now available for almost all active-ingredient groups, and thus use of CFCs in this area is no longer required. In addition to HFC-134a, HFC-227ea is also used.

The time series does not begin until 1996, the year when HFCs were first used in this area, and it shows increasing emissions, which agrees with increasing use of HFCs as substitutes for CFCs. A large change occurred in 2001. As of that year, CFCs were prohibited for the largest group of active ingredients, the short-acting beta-mimetics. In light of the increasing use of dry powder inhalers, it is likely that former CFC usage levels of over 400 t/a will no longer be reattained – at least for the medium term.

4.6.4.1.2 Methodological issues (2.F.4)

The emission data is based on figures on sales of metered-dose inhalers in Germany, as obtained via surveys of producers. A surcharge factor of 13% is applied for hospitals and doctors' samples.

In agreement with IPCC specifications (IPCC, 1996b, 2.61), a 100% emissions level (EF_{use} = 1) is assumed; this is appropriate and justified. Inhaled HFCs are not broken down in bronchial passages; they are released into the atmosphere, without undergoing any changes, upon exhalation.

Apart from doctors' samples, metered dose inhalers are purchased from chemists/pharmacies (Apotheken), for direct subsequent use. As a result, the time period between pharmacy sales and use is short. The reference figure for emissions – in contrast to IPCC equation 3.35 (IPCC, 2000) – thus is <u>not</u> the sum of half the purchases (sales) of year n-1 and half those of year n. That approach would be appropriate if the data were for produced, rather than sold, inhalers, since considerable amounts of time (for transport and storage) do pass between production and use.

The production emissions are added to the usage emissions. The EF_{use} on which production emissions is based is itself based on very precise producer determination of filling emissions. These amount to about 1%, with respect to new consumption for filling. This translates to about 0.15 g per 10 ml inhaler. Part of the emissions are collected with cold traps and then incinerated. Without such collection, the emissions would be higher.

4.6.4.1.3 Uncertainties and time-series consistency (2.F.4)

The data is considered to be of good quality. The reliability of sales data is considered high.

The surcharge factor for hospitals and doctors' samples can vary, by ±2%, from the above-cited 13%.

4.6.4.1.4 Source-specific quality assurance / control and verification (2.F.4)

Cf. Chapter 4.6.2.1.4.

4.6.4.1.5 Source-specific recalculations (2.F.4)

No recalculations have been carried out.

4.6.4.1.6 Planned improvements (source-specific) (2.F.4)

No further improvements are planned at present.

4.6.4.2 Other aerosols (2.F.4)

4.6.4.2.1 Source-category description (2.F.4)

The sub-category "other aerosols" accounted for nearly 4 % of all HFC emissions in 2004.

In Germany, six types of general aerosols (includes neither medical sprays nor novelties) containing HFC are sold:

- Compressed-air sprays (30-40%),
- Cooling sprays (30 %),
- Drain-opener sprays (30%),
- Lubricant sprays (2%),
- Insecticides (2%) and
- Self-defence sprays (2%).

Emissions from such sprays amounted to about 170 t in 2004. To these must be added "novelty" sprays (artificial snow, streamer sprays, etc.), which emit about 100 t HFC/year.

4.6.4.2.2 Methodological issues (2.F.4)

The usage emissions data is based on estimates of aerosol sales in Germany, obtained via surveys (producers/fillers, association). In keeping with IPCC specifications (IPCC, 1996b, 2.61), a 100% emissions level (EF_{use} = 1) is assumed; this is appropriate and justified. Of the sprays sold in Germany, it is assumed that one-half are used in the same year they are purchased and the other half are used in the following year.

Emissions for general aerosols also include filling emissions (= production emissions). The $EF_{production}$ is based on experts' estimations. No novelties are produced in Germany.

4.6.4.2.3 Uncertainties and time-series consistency (2.F.4)

In comparison to the emission data on metered-dose inhalers, this data is not considered to be very 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. At present, the uncertainties cannot be quantified.

Since the shift from CFCs to chlorine-free propellants had already been completed by the beginning of the 1990s, the time series has been largely unchanged since 1995.

4.6.4.2.4 Source-specific quality assurance / control and verification (2.F.4)

Cf. Chapter 4.6.2.1.4.

Collected data is checked for plausibility via comparison with data from the previous year; the reasons for any marked changes are explored.

4.6.4.2.5 Source-specific recalculation (2.F.4)

No recalculations have been carried out.

4.6.4.2.6 Planned improvements (source-specific) (2.F.4)

Improvements have been initiated in collaboration with the industry association. In addition, the possibility of using additional data sources is being reviewed. A first assessment of such data sources has shown that it may be possible to obtain the AR for "new consumption" via the Environmental Statistics Act (UstatG). And existing statistics cannot be used to survey imports and exports – and, thus, to survey domestic sales – since these statistics do not differentiate between the various relevant propellant gases.

4.6.5 Solvents (2.F.5)

4.6.5.1 Source-category description (2.F.5)

The sub-category "solvents" accounted for 0.02 % of all HFC emissions in 2004.

Use of HFCs as solvents was banned in Germany up until the year 2001 (2nd Ordinance on the Implementation of the Federal Immission Control Act – 2. BimSchV) and remains heavily restricted to this day, since individual applications must be submitted for each form of use. The applications are examined, and approval is only granted in exceptional cases. Virtually no applications are known to date. Due to the very minor importance of this sub- source category, a detailed description is not provided. The emissions figures are based on sales data from the authorised seller. EF_{use} = 1. The reader's attention is called to Table 59. Since the data is confidential, it is included in the figures for other aerosols containing HFC-134a.

4.6.6 Semiconductor manufacturing (2.F.6)

4.6.6.1 Source-category description (2.F.6)

In 2004, semiconductor manufacturing (including circuit boards, an area no longer considered separately later on, due to its low relevance) accounted for 30% of all PFC emissions, 0.02 % of all HFC emissions and 1.4% of all SF_6 emissions.

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 relevant emissions cannot be determined solely on the basis of the quantities used (sales by the gas trade). The difference between consumption and emissions results, firstly, in that only partial chemical conversion occurs in plasma reactors and, secondly, from the effects of downstream gas purification systems. Furthermore, a residue of approximately 10 % per gas bottle must be taken into account as non-consumption. The resulting emissions depend primarily on the degree to which the relevant production plants are equipped with waste-gas-scrubbing technologies.

The PFC time series shows a continual increase in emissions until the year 2000. One of the reasons for this is that the number of reporting companies doubled from 1995 to 1999 – from seven to 14. This group includes not only new plants; it also includes plants that were already producing in 1995 but not yet participating in monitoring (no extrapolations were carried out). For this reason, emissions prior to 1999 are systematically too low. Following a significant decrease in 2001, emissions have been increasing again since 2002. This is due mainly to increased production.

4.6.6.2 Description of methodology (2.F.6)

As the result of a voluntary commitment by the semiconductor industry, good emissions figures are available for this sub-source category, for all individual substances, from the year 2001 onwards. In keeping with a standardised calculation formula (Tier 2c approach), the emissions data is calculated for each production site, from annual consumption, aggregated and then reported by the German Electrical and Electronic Manufacturers Association (Zentralverband Elektrotechnik- und Elektroindustrie e.V. - ZVEI, electronic components and systems) to the Federal Environmental Agency. The basic data for calculation, the the emissions data, is not publicly accessible, but it may be inspected for review purposes. Since only emissions – and not the underlying consumption – are reported, no IEF can be provided/calculated.

4.6.6.3 Uncertainties and time-series consistency (2.F.6)

In general, the data is considered to be of very good quality.

Until the 2000 report year, emissions data was 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. This emissions data is likewise considered to be fairly accurate.

4.6.6.4 Source-specific quality assurance / control and verification (2.F.6)

Cf. Chapter 4.6.2.1.4.

In addition, the data has been checked for plausibility, and the association has subjected it to an internal quality assurance / control and verification process.

4.6.6.5 Source-specific recalculation (2.F.6)

No recalculations have been carried out.

4.6.6.6 Planned improvements (source-specific) (2.F.6)

At present, no further improvements are planned.

4.6.7 Electrical equipment (2.F.7)

4.6.7.1 Source-category description (2.F.7)

The sub-category "electrical equipment" accounted for 14 % of all SF_6 emissions in 2004.

Electrical equipment for power supply is by far the largest single consumer of SF_6 in Germany. Given the high export ratio of over 80 %, however, only a small proportion of consumption is added to new equipment and systems in the national inventory.

SF_6 is used primarily in switching systems and equipment in high-voltage (110-380 kV) and, increasingly, in medium-voltage (10-30 kV) networks. The gas, which is used instead of air, serves as both a fire retardant and insulator. It is not commonly used in the low-voltage segment (< 1 kV).

Furthermore, SF_6 is used in the manufacture of components for switching systems. The emission factors for manufacture of these components are markedly higher.

As a result of first-time inclusion, in the 2002 report year, of additional SF_6 applications, the time series shows a marked jump in emissions in 2002. In contrast to the high-voltage sector, which is growing only slowly, the medium-voltage sector is growing dynamically. The volume of products in service increased sharply from 1995 to 2004. Due to the low EF_{use} (see above) involved, the relevant emissions grew to a smaller degree.

4.6.7.2 Description of methodology (2.F.7)

Since 1996, emissions have been determined on the basis of a highly detailed concept developed by the Federal Environmental Agency in collaboration with manufacturers and operators. The data are collected by the German Electrical and Electronic Manufacturers Association (ZVEI), the Association of German Network Operators (VDN) and the Association of the Energy and Power Industry (VIK). The installed quantity at the end of a given year and the emissions at the relevant individual sources (manufacturers' factory losses, manufacturers' assembly losses, leakage at operators' facilities (including maintenance), and disposal) are ascertained:

1. SF_6 emissions in production

Production emissions are determined separately, in keeping with their occurrence at the plant or installation site of the relevant domestic operator:

a) Domestic plant losses, especially losses occurring in development and in filling for product checks (about 95% of production emissions), broken down by high-voltage gas-insulated switching systems, high-voltage power switches, medium-voltage switching systems and high-voltage/medium-voltage components.

b) Domestic installation / assembly losses (ca. 5%) for high-voltage-gas-insulated switching systems, high-voltage power switches, medium-voltage switching systems and outdoor high-voltage transformers. In components that are part of high-voltage gas-insulated switching systems (inlets, voltage converters), no losses occur in assembly that are not counted with those for high-voltage gas-insulated switching systems.

Domestic plant and assembly/installation losses were considered; these, in turn, were broken down by high-voltage gas-insulated switching systems, high-voltage power switches and medium-voltage switching systems – i.e. products that go directly to domestic or foreign operators. Reporting did not include emissions from production of components purchased by switching-system manufacturers (such as transformers and inlets for high-voltage gas-insulated switching systems, medium-voltage converters). Emissions from production of outdoor transformers were also not reported. Via intensive discussion (monitoring, measures), SF_6 applications in component production were identified; these were included in reporting for the first time in the 2002 report year.

The emissions data is based primarily on a mass balance and not on the calculation using EF and AR.

2. Usage emissions

Ongoing emissions from products in service include the amount of SF_6 in service, as accumulated since 1970 via annual additions of switching systems; they are given as the average for year n. This mean amount in service for a given year n is half of the sum of the final amount for the previous year (n-1) and of the final amount for the current year (n).

The final amount of SF_6 in all electrical equipment for a given year n changes annually by the balance of new additions and removals. Some removals (high voltage) have been registered since 1997; systematic removals of products from entire years cannot be expected before 2010, in light of the products' estimated 40-year service lifetime.

Three special aspects must be taken into account in reporting relative to switching systems.

a) 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 switching systems, because operators/manufacturers estimated the SF_6 stocks in service for 1995. Their estimate was broken down into high voltage and medium voltage (770 t and 157.6 t, respectively).

b) In the area of high voltage, stocks in service and emissions are determined not via the above-cited equation but via regular direct surveys of the some 100 operators. These operators are surveyed directly with regard to their current stocks of SF_6 in operating equipment (gas-insulated switching systems, power switches, outdoor converters) and to their annual refilling (for operating equipment) to compensate for emissions.

c) The group of operators of medium-voltage switching systems is very numerous and highly diverse. It is thus not feasible to conduct direct surveys. Manufacturers of medium-voltage systems have themselves taken responsibility for updating their domestic stock data on the basis of their sales data. Emissions determination is possible in that the systems are practically maintenance-free and have only minimal emissions (usually only as a result of external influences), emissions that can be taken into account by means of a lump-sum emissions factor (survey 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 considered not only "closed for life", but also "sealed for life". As a result, the impact of older systems with emissions rates greater than 0.1% has diminished.

3. Disposal emissions

Because switching systems have long service lifetimes (40 years), and because the first use of SF_6 dates from the late 1960s, disposal emissions are just now beginning to occur, on a small scale. The amounts of SF_6, from old high-voltage systems, that now need to be disposed of thus simply have been roughly estimated to date (at a constant 3 t/a). As of the 2005 report year, the relevant associations plan to precisely determine amounts for disposal from systems removal for the first time. For this reason, plans call for first provision of a precise methods description next year. Emissions from disposal have been estimated at 0.06 t to date.

4.6.7.3 Uncertainties and time-series consistency (2.F.7)

Since there are only about ten different manufacturers of high-voltage operating equipment (including inlets and transformers), the consumption data is very reliable – especially since, in principle, the data consists of purchasing data for which internal records are kept. 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 for testing, in empyting of devices following 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, as well as 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.

The data for the medium-voltage sector can be considered very reliable, since it is based on sales data. Each company keeps lists of the numbers of switching systems it sells within the country each year, together with the pertinent standard SF_6 fill amounts.

Emissions from production of switching systems and devices have decreased markedly since 1995. The implicit emission factor decreased from 4.7% in 1995 to 1.3% in 2004. The main reason for this consists of considerably reduced plant losses in connection with high-voltage gas-insulated switching systems. This, in turn, is a result of more careful plant handling of SF_6. Domestic installation losses ("on site") have decreased sharply for all products – and, again, most sharply for high-voltage gas-insulated switching systems.

The emissions rate of 0.1% in the medium-voltage sector may be considered acceptable for the stocks from recent years. Since the VDN has always, in its surveys, included queries concerning refills of medium-voltage systems, samples for checking can now be taken: VDN documents show SF_6 losses of only 0.06% for medium-voltage switching systems (circuit breakers) in the years 1998/1999.

Emissions in the high-voltage sector are determined via refilling, which is carried out by operators' own personnel or by manufacturers' service networks. (Refilling is carried out when the fill level drops below 90% of the desired fill level; normally, devices are equipped to show any need for refilling). This method can be considered very reliable, i.e. the deviations from the actual value are about ±10%. All surveys to date have produced similar results for emissions; all results are within a range from 0.88 to 0.82%.

In the year 2000, an unusual development occurred in high-voltage in-service stocks and, thus, in emissions, both of which had been increasing since 1995: a decrease with respect to the previous year. For in-service stocks, the decrease amounted to over 25 t, while for emissions it amounted to 0.85 t. This decrease, which is due to trends in high-voltage gas-insulated switching systems (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 VDN, which carries out the surveys, 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 these changes, the staff responsible for operating equipment in service was repeatedly replaced. As a result, it is possible that double-counting occurred in 1999, and that some operating equipment was not counted in 2000.

4.6.7.4 Source-specific quality assurance / control and verification (2.F.7)

Cf. Chapter 4.6.6.4.

4.6.7.5 Source-specific recalculation (2.F.7)

The data is being recalculated on an ongoing basis. Figures provided by associations are checked by an external expert and entered into the CSE database. In addition, where possible, the data is checked by the relevant Federal Environmental Agency specialist.

4.6.7.6 Planned improvements (source-specific) (2.F.7)

Discussion is currently in progress, within the EU, on standardisation of existing monitoring systems. Similar discussion is being carried out in connection with revision of the IPCC guidelines for reporting. In the process, discussion on the German monitoring system is being welcomed. Proposals for improvement that emerge from such discussion could thus lead to changes in the monitoring system.

4.6.8 Others (2.F.8)

4.6.8.1 Sports shoes (2.F.8)

4.6.8.1.1 Source-category description (2.F.8)

The sub-category "sports shoes" accounted for 2% of all SF_6 emissions in 2004. SF_6 is used in soles of athletic shoes in order to improve shock absorbency. Since 2004, a switch to PFC-218 has been taking place.

4.6.8.1.2 Description of methodology (2.F.8)

The emissions data (relevant sales of such sports shoes in Germany and, hence, the total quantity in Germany) is based on manufacturers' information with regard to the EU. These figures have been broken down, on the basis of Germany's population, to obtain figures for Germany. The data has been available to the Federal Environmental Agency since the 2001 report year, but it is published only in aggregate form, for reasons of confidentiality.

The emissions may be considered equivalent to the amounts used, although, by analogy to the IPCC method (IPCC, 2000: Equation 3.23) for automobile tyres, a delay of three years is assumed.

4.6.8.1.3 Uncertainties and time-series consistency (2.F.8)

In spite of the good quality of the data for the EU, the breakdown by Member States is subject to not inconsiderable uncertainties.

The relevant uncertainties cannot be quantified.

4.6.8.1.4 Source-specific quality assurance / control and verification (2.F.8)

This is not carried out, due to the insignificance of this emissions source.

4.6.8.1.5 Source-specific recalculation (2.F.8)

No recalculations have been carried out.

4.6.8.1.6 Planned improvements (source-specific) (2.F.8)

No improvements are needed. SF_6 was used for the last time in 2003.

4.6.8.2 AWACS (airborne warning and control system) maintenance (2.F.6)

4.6.8.2.1 Source-category description (2.F.8)

The sub-category "AWACS maintenance" accounted for 4% of all SF_6 emissions in 2004.

SF_6 is used as an insulating medium for radar in 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. The emissions data is based on information provided regarding quantities consumed in filling/refilling NATO's NAEWF fleet. The emissions figures for report years until 2001 are based on estimates made via a 1996 survey. The emissions data for the years 1997 to 2001 is thus imprecise. New surveys of consumption quantities were carried out for the 2002 report year. They showed a significant increase over the 2001 report year.

A detailed description is not provided, however, due to the low significance of this sub-source category.

4.6.8.3 Automobile tyres (2.F.8)

4.6.8.3.1 Source-category description (2.F.8)

The sub- source category "automobile tyres" accounted for 2% of all SF_6 emissions in 2004.

In the past, automobile tyres were filled with SF_6 for reasons of image (the resulting improved pressure constancy is not relevant in practice). Because of the climate relevance of SF_6, tyre manufacturers have stopped advertising this application. This has led to a considerable reduction. The bulk of today's emissions originates from gas in old tyres.

The peak consumption year was 1995, when over 500 of the 3,500 or some tyre-sales outlets in Germany had the option of filling tyres with SF_6 gas. Emissions are determined on the basis of consumption quantities, which are obtained from gas dealers and manufacturers (SF_6). In each case, emissions follow consumption with a time lag of approximately 3 years, when the tyre is dismantled. This assumption is in keeping with the IPCC method (cf. Table 59).

A detailed description is not provided, however, due to the low significance of this sub-source category.

4.6.8.4 Insulating glass windows (2.F.8)

4.6.8.4.1 Source-category description (2.F.8)

The sub-category "insulating glass windows" accounted for 29% of all SF_6 emissions in 2004.

Insulated multiple glazing gained popularity over single-glazing for windows and glass facades in the 1970s, and since 1975 SF_6 has been filled into the cavity between the glazing to enhance noise insulation. At present, emissions from sound-proof windows represent the largest source of SF_6 emissions. However, the slight improvement in soundproofing obtained by using SF_6 tends to have a negative effect on thermal insulation performance. The higher priority given to thermal insulation – e.g. by the Thermal Insulation Ordinance

(Wärmeschutzverordnung) – along with awareness of the higher greenhouse potential of SF_6, have led to a reduction in use of SF_6 in this application since the mid-1990s.

The decreases in production emissions result from decreases in consumption and are proportional to them. They respond very flexibly to changes in consumption. Unlike emissions from in-service stocks or disposal, this form of emissions is immediately terminated by discontinuation of filling. The time series for emissions from in-service stocks and disposal reflect use in previous years.

4.6.8.4.2 Description of methodology (2.F.8)

The emissions data consists of:

1. Production emissions (= $EF_{production}$ * new domestic consumption (AR)),
2. Use emissions (= EF_{use} * systems in service (AR)),
3. Disposal emissions ($EF_{disposal}$ * remaining products (n-25)).

Production emissions (filling losses resulting from overfilling) occur solely in the year of relevant production. Experts indicate that in filling of cavities between panes, about one-third of the SF_6 consumed is lost. The $EF_{production}$ is thus 33%, with respect to new annual consumption. 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 the 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 represents one-third (33%) of the relevant consumed amounts.

Since the technique used to fill windows (slow inflow via a drilled hole or pried-open crack, usually from the bottom to the top, and at atmospheric pressure) has remained unchanged for many years, and since the spectrum of window shapes has not changed significantly, it is unlikely that the emission factor has changed. It is treated as a constant.

The new annual consumption is determined via top-down survey (domestic sales by the gas industry)

Use and "stock" emissions consist of gas losses from filled panes; they total approximately 1 % per annum throughout panes' entire service lifetimes, which average 25 years. The final SF_6 stocks for year n change annually, through additions and removals. Since the products' service lifetime is 25 years, systematic removals did not begin until 2000. Ongoing emissions from products in service refer to the total amount of SF_6 in service, as accumulated since 1975 via annual additions in installed windows; they are given as the average for year n. This mean amount in service for a given year n is half of the sum of the final amount for the previous year (n-1) and the final amount for the current year (n).

A DIN standard (DIN, 1989: DIN 1286, Part 2) specifies an upper limit of 10 per mil for annual losses of filled gas from panes' peripheral seals. Experts agree that the actual gas losses are normally considerably lower, as long as windows remain intact. Nonetheless, a level of 1 % ongoing gas losses may be considered realistic, in light of the need to take account of glass breakage during transport, installation and use, and of leakage from peripheral seals, which increases with windows' age.

Finally, disposal losses are incurred at the end of panes' service lifetimes (utilisation periods), or an average of 25 years after the filling emissions. Since each year a window loses 1 % of its gas level from the previous year, windows dating from a given year will no longer contain their original filling when they are disposed of 25 years later; their fill levels will have been reduced by 25 ongoing per-year losses. Since no recycling takes place, the entire amount disposed of becomes emissions ($EF_{disposal}$ = 1).

4.6.8.4.3 Uncertainties and time-series consistency (2.F.8)

The data for annual new consumption, which is based on commercial sales data, may be considered sufficiently reliable and complete. For practical reasons, producers' sales data cannot be used as bottom-up check sample – the number of producers, at nearly 400, is too large.

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 (see above).

4.6.8.4.4 Source-specific quality assurance / control and verification (2.F.8)

Cf. Chapter 4.6.2.1.4.

In 2001, quality assurance / control and verification were carried out via plausibility control, with the aid of the calculation model.

4.6.8.4.5 Source-specific recalculation (2.F.8)

No recalculations have been carried out.

4.6.8.4.6 Planned improvements (source-specific) (2.F.8)

Because prohibition of this application is expected, no further improvements are planned.

4.6.8.5 Trace gas (2.F.8)

4.6.8.5.1 Source-category description (2.F.8)

In 2004, the sub- source category "trace gas" accounted for 0.3% of SF_6 emissions.

SF_6, as a stable and readily detectable trace gas, even at extremely low concentrations, is used to investigate ground-level and atmospheric airflows and gas dispersions. Emissions may be equated with the quantities used. The quantities used are determined via experts' estimations. Relevant surveys are conducted only around every five years (1996, 2002) since, according to experts, the quantities used vary only minimally.

A detailed description is not provided, however, due to the low significance of this sub-source category.

4.7 Other Areas (2.G.)

No other sources of greenhouse-gas emissions are known.

5 SOLVENTS AND OTHER PRODUCT USE (CRF SECTOR 3)

This source category comprises emissions from the use of chemical products. Currently, the source category includes information on solvent emissions from applications in industry, trade and commerce and households, as well as detailed information about release of N_2O during its use. Emissions from direct use of CO_2 in products have been neglected to date. The inventories do not take account of chemical processes in the atmosphere by which released carbon (for example, in NMVOC) is transformed into CO_2.

Source category 3 Solvents and other product use is subdivided into the categories listed above in Figure 40. In the CSE, "Other" (3.D) includes emissions of laughing gas (cf. Chapter 5.2), emissions from SCR systems and the above-detailed other solvent uses that cannot be allocated to source categories 3A through 3C.

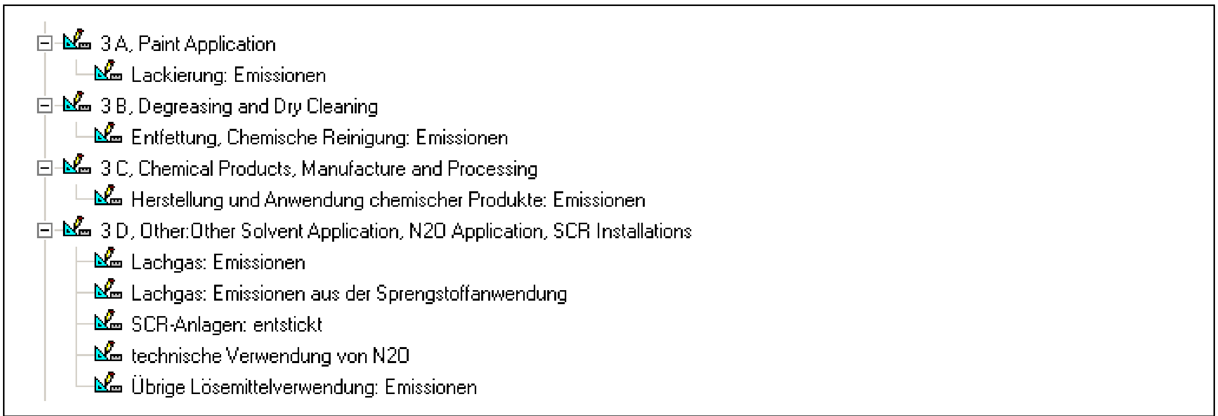


Figure 40: Structural allocation, source category 3 Solvents and other product use

N_2O emissions from source category 3.D Other are reported separately from the other parts of Chapter 5.2, since emissions from substance release of N_2O, in the various possible applications, have been studied in a research project and are now reported in greater detail. This research project considered the various pertinent potential emissions sources (including explosives production), as listed in the IPCC Good Practice Guidance (2000), and it will specify methods, prepare documentation, carry out relevant recalculations and make pertinent additions to the inventory.

NMVOC emissions from source category 3.D Other continue to be reported in combination with emissions from 3.A through 3.C (cf. Chapter 5.1), since they were not covered by the aforementioned research project.

5.1 Solvents - NMVOC (3.A-3.C & 3.D)

5.1.1 Source-category description (3.A-3.C & 3.D)

CRF 3A - 3C, 3D (NMVOC)					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
	- / -				

Gas	CO_2	CH_4	HFC	PFC	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)	NE	NO	NO	NO	NO	CS	NO	NO	CS	NO
EF uncertainties in %										
Distribution of uncertainties										
Method of EF determination										

The source category NMVOC emissions from the area of Solvents and other product use (CRF 3.A-3.C and 3D) is not a key category for purposes of reporting of greenhouse-gas inventories.

The NMVOC emissions released through use of solvents and solvent-containing products all belong to sub-categories of this source category.

The four reporting categories vary widely in structure. To take account of this variation, data surveys for the present report were carried out with the UNECE/EMEP sub-structures based on the CORINAIR97 (CORINAIR: **CO**ordination d' **IN**formation Environmentale; sub-project **AIR**) SNAP system[31] .

Category 3D "other" includes the following applications and activities:

- Treatment of glass and rock wool
- 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[32]. For purposes of the definition of solvents, the term "solvent use" is also defined in keeping with the EC solvents directive[33].

It is important to note, however, 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

31 In the present area, this involves "SNAP Level 3" detailing.
32 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.
33 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.

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 source category.

Delimitation of this source category as outlined above takes a highly diverse range of emissions-causing processes into account. This applies for:

- 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.

5.1.2 Methodological issues (3.A-3.C & 3.D)

NMVOC emissions are calculated in keeping with a product-consumption-oriented approach. In this approach, the NMVOC input quantities allocated to these source categories, via solvents or solvent-containing products, are determined and then the relevant NMVOC emissions are calculated 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 source category.

Use of this method is possible only with valid input figures – differentiated by source categories – in the following areas:

- 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 the sub-categories 3A – 3D, these input figures are determined on the level of 37 differentiated source areas (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 dialog) relative to the various source categories and source-category areas. These efforts lead to the NMVOC emissions from solvent use shown in Table 62.

Table 62: NMVOC emissions from solvent use in 2002

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	NMVOC [Gg]
Total solvent and other product use	**749.962**
A. Paint application	291.157
B. Degreasing and dry cleaning	42.958
C. Chemical products, manufacture and processing	35.429
D. Other (as specified)*	380.418

Not all of the necessary basic statistical data required for calculation of NMVOC emissions in 2003 and 2004 is available; as a result, the data obtained for 2002 will continue to be used in current reporting. For this reason, it is expected that this data will be revised later on. Since 1990, so the data, NMVOC emissions from use of solvents and solvent-containing products have decreased by about 35 %. The greatest part of this emissions reduction has occurred in the past four years. This successful reduction occurred especially as a result of regulatory provisions such as the 31st Ordinance on the execution 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 TA Luft. The German "Blauer Engel" ("Blue Angel") environmental quality seal, which is used to certify a range of products, including low-solvent paints, lacquers and glues, 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 more than compensated for 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.

5.1.3 Uncertainties and time-series consistency (3.A-3.C & 3.D)

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 source areas). Table 63 shows the thus-determined error ranges for the report categories.

Table 63: Experts' assessment of uncertainties (Tier 1)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Uncertainties	
Total solvent and other product use	**+ 32,4 %**	**- 31,8 %**
A. Paint application	+ 32,0 %	- 33,6 %
B. Degreasing and dry cleaning	+ 71,5 %	- 50,6 %
C. Chemical products, manufacture and processing	+ 9,9 %	- 10,8 %
D. Other (NMVOC)	+ 30,1 %	- 30,0 %

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 source areas with highly differing emissions conditions.

5.1.4 Source-specific quality assurance / control and verification (3.A-3.C & 3.D)

The NMVOC-emissions data for 2001 and 2002, as used in the emissions inventory, was obtained via a research project and was evaluated, in the framework of this project, for methodological and material consistency, plausibility and completeness. In the course of this review, the relevant methods were optimised in co-operation with the affected industry sectors.

Comparisons with older emissions calculations involve product-based reviews, as well as correction of errors resulting from erroneous production statistics. In the past, relevant quantities (> 100 kt) of base substances for the chemical industry were erroneously reported as "other organic solvents". This correction led to a reduction – also amounting to ca. 100 kT – of total emissions in the area of source category 3.

5.1.5 Source-specific recalculations (3.A-3.C & 3.D)

As a result of repeated changes in the underlying basic statistical systems, it is difficult to carry out consistent source-specific recalculation for NMVOC emissions; as a result, such recalculation is not currently planned.

5.1.6 Planned improvements (source-specific) (3.A-3.C & 3.D)

To reduce data uncertainty in the area of NMVOC, for other emissions-relevant source-category areas, plans call for comparing the input figures used (quantities and VOC concentrations) with industry data.

In addition, as part of periodical updates of source-category emissions, additional discussions will have to be carried out with industry associations, aimed at reaching agreements on regular provision of differentiated industry data. Relevant activities are planned for the 1st half of 2006.

The possibility of including emissions calculations for CO_2 within this source category will be reviewed in 2006, via analysis of other countries' reporting.

5.2 Other - N_2O (3.D)

5.2.1 Narcotic use of N_2O (3.D.1)

5.2.1.1 Source-category description (3.D.1)

CRF 3.D.1					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
	- / -				

Gas	CO_2	CH_4	HFC	PFC	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF) Narcotic use of N_2O						CS				
EF uncertainties in %										
Distribution of uncertainties						N				
Method of EF determination						CS				

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 result from production and filling of the gas in gas tanks; the emissions occur only in use of the gas. Medical applications represent the most important N_2O-emissions source. In addition, food-technology applications, and various other technical applications, can be considered possible sources.

N_2O in medical applications

In medicine, nitrous oxide, which has analgesic properties, is used for narcotic purposes. It is the oldest narcotic in use, and it is among those with the fewest side-effects. 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 narcotics. Globally, medical N_2O emissions account for some 10 % of total nitrous oxide emissions (INNOVATIONS-REPORT, 2004). While medical use of N_2O is not prohibited, there is strong resistence – especially among German anaesthetists – against widespread, general use of the substance.

Use of xenon as an anesthetic could bring about a further reduction of N_2O emissions. Xenon is the only noble gas that exhibits anesthetic properties at normal pressure. The narcotic effects of xenon are 1.5 times stronger than those of nitrous oxide. The gas is expected to be certified in fall 2005 for use in Germany. Certification for the entire EU region is expected to follow later. On the other hand, in light of its overall properties and its availability, xenon cannot serve as a substitute for nitrous oxide – only as a supplement.

N_2O-emissions trends are summarised in Table 64. 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 narcotic purposes had existed in the former GDR. At the time, the plant had not yet been operational for long (it was constructed in 1988). The annual production capacity was approximately 1200 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_2O emissions of 6200 t were estimated, as a rough approximation, for Germany in 1990. The N_2O figure for 2001 was obtained via a written memorandum of the Industriegaseverband e.V. (IGV) industrial-gas association. This figure was tied to a range of 3,000 ~ 3,500 t/a. The mean value from this range (3,250 t/a) was then used for generation of an N_2O-emissions time series. Due to a lack of other data, a linear reduction of N_2O use in this sector is assumed between 1990 and 2001 (see Table 64).

Table 64: Time-series trend for N_2O emissions in medical uses in the Federal Republic of Germany, 1990-2005

Application	Units	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Medicine	N_2O [t/a]	6200	*5932*	*5664*	*5395*	*5127*	*4859*	*4591*	*4323*	*4055*	*3786*	*3518*	3250	3250	3250	3250

The numbers in italics are interpolated and extrapolated values

The reduction in N_2O use in this period results from acceptance of the "low-flow method"[34] and a "Say-no-to-N_2O" posture. Use would increase in future only if nitrous oxide were

[34] The "low-flow method" is a form of anasthesia in which only very small amounts of fresh gas are used; this can greatly reduce N_2O emissions (Schmidt, 2001)

commonly used to assist mothers giving birth (as is customary in the U.S. and the UK) or if it became an accepted painkiller in trauma medicine. Since no reliable figures are available to support assumptions that the reducing trend will continue, a conservative perspective is applied, in the framework of a "worst-case scenario", and N_2O emissions are expected to remain constant between 2002 and 2004. The reference to this assumption as a "worst-case scenario" is based on the fact that N_2O use shows a falling trend since 1990. The so-estimated values for the period as of 2002, and the values calculated via linear interpolation for the period between 1990 and 2001, are shown in Table 64 in *italics*.

The "worst case" is shown in Figure 41 as a solid line, while the linearised trend appears as a dotted line.

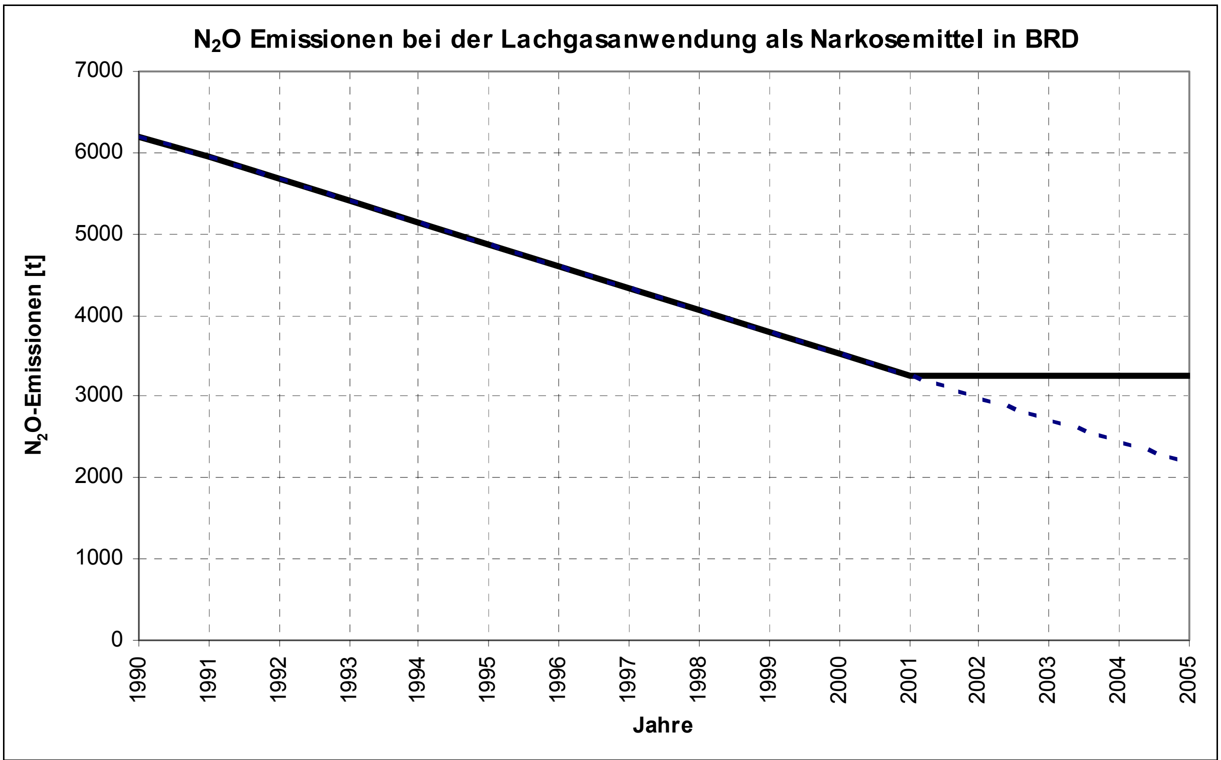


Figure 41: Development of N_2O emissions in medical uses (1990-2005)[35]

N_2O use in the food industry

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 food to which N_2O is added include whipped cream (from spray cans), the dairy product known in Germany as "quark", and various types of desserts, such as ready-to-eat puddings. Nitrous oxide is generally certified for use with foods; no maximum amounts that may not be exceeded are mandated. Use of nitrous oxide as a food additive is considered safe. (DIE VERBRAUCHER INITIATIVE E.V, 2005; LINDE GAS GMBH, 2005)

Relevant research was not able to turn up any data from which the amounts and trends of N_2O emissions in the food sector could be derived. The agency commissioned to carry out

[35] N_2O emissions from narcotic use of nitrous oxide in the FRG; years

the research[36] was informed, however, that the N_2O amounts involved are small (less than 5 %) and thus are insignificant.

N_2O in technical applications

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, 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).

In automotive technology, nitrous oxide is used to improve combustion in gasoline / petrol engines, via so-called "laughing-gas injection". This "tuning" tactic can quickly increase engine performance. In Germany, relevant systems are not certified by the TÜV technical certification agency. They are thus illegal and are not considered in the present context.

For the technical-applications sector, there is also a lack of any statistics that could be used to estimate N_2O emissions. At the same time, the amount of N_2O in question is considerably smaller than the relevant N_2O-emissions amounts from medical applications. As a result, this sector plays a minor role in the area of "product use"[37].

5.2.1.2 Methodological issues (3.D.1)

With regard to development of N_2O-emissions time series for product use, to date only N_2O emissions from medical applications have been actually determined. At the same time, this approach is justified, since this sector is the main source of N_2O emissions in the area of product use, accounting for 90 % of such emissions (SCHÖN et al., 1993, page 82). The remaining 10 % can be broken down into technical applications (less than 10 %[38]) and food-technology applications (less than 5 %[39]) . From this information, the pertinent share for the food-technology industry is estimated at 3 %, and thus the corresponding share for the "technical applications" area is estimated at 7 %, the difference between the total remaining share (10 %) and the 3 % for foods.

Table 65 shows the time series trend for N_2O emissions for medical and "other" applications, and their sums, for the period 1990 through 2005. Here, "other" applications is a combination of food-technology applications and technical applications. The N_2O-applications distribution in 2001 is 90 % for medical applications and 10 % for other applications. In the time-series trend, a constant N_2O-emissions level is assumed in the "other" area, since no detailed figures on trends in this sector are available.

[36] Personal communication from the Industriegaseverband e.V. (IGV) industrial-gas association
[37] Written communication from the Industriegaseverband e.V. (IGV) industrial-gas association
[38] Personal communication from the Industriegaseverband e.V. (IGV) industrial-gas association
[39] Personal communication from the Industriegaseverband e.V. (IGV) industrial-gas association

Table 65: Time-series development for N_2O emissions, with assumed constant N_2O emissions in the "other" sector

Area	Units	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Medicine	N_2O [t/a]	6200	*5932*	*5664*	*5395*	*5127*	*4859*	*4591*	*4323*	*4055*	*3786*	*3518*	3250	3250	3250	3250
Other	N_2O [t/a]	361	361	361	361	361	361	361	361	361	361	361	361	361	361	361
Total	N_2O [t/a]	6561	6293	6025	5757	5488	5220	4952	4684	4416	4147	3879	3611	3611	3611	3611

Numbers in italics: interpolated and extrapolated values

In product use, the input nitrous oxide escapes into the air directly and completely. As a result, the emission factor for this sector is 1 t/t, for all years in question.

Table 66: Time-series development for N_2O emission factors, with assumed constant N_2O emissions in the "other" sector

Area	Units	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Medical applications	[t/t]	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Other applications	[t/t]	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

5.2.1.3 Uncertainties and time-series consistency (3.D.1)

The uncertainty in the time-series trend for product use results from the following data spectrum and assumptions:

- N_2O use in 2001: 3,000 t ~ 3,500 t/a
- Constant level, or linear reduction of N_2O emissions from 2002 to 2004

From these figures, values for maximum and minimum N_2O emissions can be estimated. The reference figure for the uncertainty calculation is defined as 3250 t/a. In the process, the aforementioned distribution is retained (medical applications in 2001 at 90 %; constant N_2O level for the "other" sector between 1990 and 2005). These figures lead to the following theoretically possible combinations:

4. N_2O emissions in 2001 3500 t/a;
   constant level for N_2O emissions from 2002 through 2004
5. N_2O emissions in 2001 3500 t/a;
   linear reduction of N_2O emissions from 2002 through 2004
6. N_2O emissions in 2001 3,000 t/a;
   constant level for N_2O emissions from 2002 through 2004
7. N_2O emissions in 2001 3,000 t/a;
   linear reduction of N_2O emissions from 2002 through 2004

Consequently, 1) shows the maximum possible N_2O amount, while 4) shows the minimum possible N_2O amount. Table 67 shows the maximum emission level (case 1) for the period 1990 through 2005, while Table 68 shows the minimum emissions level (case 4) for the same period. Here as well, the values for 1991 through 2000 are calculated via linear interpolation, while the values for the period 2002 through 2004 are obtained via extrapolation.

Table 67: Time-series development for N_2O emissions in the "product use" sector, with the assumption that 3500 t/a was used in medical applications in 2001 (maximum emissions levels)

Area	Units	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Medicine	N_2O [t/a]	6200	5955	5709	5464	5218	4973	4727	4482	4236	3991	3745	3500	3500	3500	3500
Other	N_2O [t/a]	389	389	389	389	389	389	389	389	389	389	389	389	389	389	389
Total	N_2O [t/a]	6589	6343	6098	5853	5607	5362	5116	4871	4625	4380	4134	3889	3889	3889	3889

Table 68: Time-series development for N_2O emissions in the "product use" sector, with the assumption that 3,000 t/a was used in medical applications in 2001 (minimum emissions levels)

Bereich	Units	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Medicine	N_2O [t/a]	6200	5909	5618	5327	5036	4745	4455	4164	3873	3582	3291	3000	2709	2418	2127
Other	N_2O [t/a]	333	333	333	333	333	333	333	333	333	333	333	333	333	333	333
Total	N_2O [t/a]	6533	6242	5952	5661	5370	5079	4788	4497	4206	3915	3624	3333	3042	2752	2461

From these figures (Table 64, Table 67, Table 68), the uncertainties can be summarised as follows: Between 1990 and 2001, a symmetric uncertainty can be seen in both directions (U_{min} and U_{max}). From 1990 to 2001, U_{max} shows a linear increase in the uncertainty that reaches a level of 8 %. As of 2001, this value remains constant. U_{min} also shows a linear progression between 1990 and 2001. Its increase as of 2001 is much larger, however, reaching an uncertainty level of –40 % in 2005.

With these results, the time series can be considered to show a normal distribution (distribution type).

Table 69: Uncertainties for development of N_2O time series in the "product use" sector, 1990-2005

Uncertainty	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
U max [%]	0 %	1 %	1%	2%	2%	3%	3%	4%	5%	6%	7%	8%	8%	8%	8%
U min [%]	0 %	-1 %	-1%	-2%	-2%	-3%	-3%	-4%	-5%	-6%	-7%	-8%	-16%	-24%	-32%

The uncertainty in the emission factors 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.

5.2.1.4 Source-specific quality assurance / control and verification (3.D.1)

For reporting, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents. The data for this source category was collected by an external expert, on behalf of the Federal Environmental Agency. Quality control was carried out by the external expert.

The figures for 2001 were obtained via direct enquiry of the IGV; as a result, the data for that year can be considered to be of higher quality. No data verification was carried out for the other years in question.

5.2.1.5 Source-specific recalculations (3.D.1)

Source-specific recalculations were carried out for nitrous-oxide-emissions levels for the period 1991 through 2004, since current data was obtained for 2001. The relevant data is presented in Table 8a of the CRF reporting tables.

5.2.1.6 Planned improvements (source-specific) (3.D.1)

No improvements are planned at present. At the same time, plans call for close cooperation with the Industriegaseverband e.V. industrial-gas association to continue in future, so that it will remain possible to obtain data.

5.2.2 Explosives (3.D)

5.2.2.1 Source-category description (3.D)

CRF 3.D					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
	- / -				

Gas	CO_2	CH_4	HFC	PFC	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF) Explosives						CS				
EF uncertainties in %						±40 %				
Distribution of uncertainties						N				
Method of EF determination						CS				

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[40] , 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 44g/mole amatol (80%-AN)) per kilogramm 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 formation in detonation of explosives with ammonium nitrate

In 2003, a total of 59 kt of explosives was produced in Germany. Of this figure, 13 kt were exported abroad, and 5.8 kt were imported into the Federal Republic of Germany[41] . This yields a figure of 51.8 kt for the amount of explosives used in Germany. Of this amount, ANFO accounts for a share of 60 %, emulsion explosives account for 25 % and dynamite accounts for 15 %. ANFO explosives consist of 94 % ammonium nitrate and 6 % fuels. The corresponding relationship for emulsion explosives is 80 % to 20 %; for dynamite, it is 50 % to 50 %.

At present, nitrous oxide amounts in detonation clouds are not determined, while amounts 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 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[42], 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).

5.2.2.2 Methodological issues (3.D)

According to the Federal Office for Material Research and Testing (BAM), levels of explosives use in Germany remained constant from 1990 to 2005.

The N_2O-emissions amount estimated above represents only the theoretically maximum emittable amount. No information is available as to distribution, i.e. as to the number of detonations that would be required to emit this maximum amount of N_2O. For this reason, it is also assumed here that detonations are carried out primarily as "controlled" detonations[43] , and that thus the maximum N_2O-emissions levels are seldom attained.

No figures are available to permit determination of the amounts of N_2O emissions actually emitted upon detonations. The above figure (68 g N_2O per kg AN) is a theoretical one, and it could be far off the actual value. When a 5 % emissions rate is assumed the N_2O amount is 3.4 g. This figure is of the same order as the maximum emissions rate (2 g) given by BENNDORF (1999, page 4), a figure that corresponds to about 3 % of the above-determined theoretical maximum N_2O emissions level. For a "worst-case scenario", the time-series trend in this project is calculated using the higher value (3.4 g).

[40] Amatol x/y : military explosives. pourable mixtures, i.a. of x % TNT and y % ammonium nitrate
[41] Personal communication: Federal Office for Material Research and Testing (BAM).
[42] 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
[43] A "controlled" detonation is one on which an effort is made to achieve an ideal detonation. In an ideal detonation, chemical reactions within the detonation front are practically complete. Factors such as temperature, pressure, fuzes, etc. can influence such reactions.

Table 70: Time-series trend, 1990-2005, for N_2O emissions from explosives use

Area	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Explosives[t/a]	51800	51800	51800	51800	51800	51800	51800	51800	51800	51800	51800	51800	51800	51800	51800
N_2O 5% [t/a]	176	176	176	176	176	176	176	176	176	176	176	176	176	176	176

To determine the relevant emission factors in kg/t, the explosives amounts involved are used. Together with the above-presented time-series trend for N_2O emissions, the time-series trend for the pertinent emission factors can also be obtained:

Table 71: Time-series trend, 1990-2005, for N_2O emission factors for explosives use

Area	Units	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Explosives	[Kg/t]	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4

5.2.2.3 Uncertainties and time-series consistency (3.D)

It is not known how explosives use has developed over the years in question. What is more, N_2O emissions are not measured upon detonation, as industry sources report, and thus no information regarding average amounts of N_2O emissions can be provided. Here, it is assumed that the reference value for the uncertainty calculation is 5% of the theoretically attainable maximum value. Within the framework of an experts' assessment, the minimum amount is set at 3 % (cf. Chapter 5.2.2.2). The same deviation (2 %) is used for the maximum value, and thus U_{max} is 7 % (cf. Table 72). A normal distribution is assumed. This basis yields the following uncertainties for the above-determined time-series trend (Table 73).

Table 72: Time-series trend for N_2O emissions from explosives use (3 %, 5 %, 7 %)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
N_2O 7% [t/a]	247	247	247	247	247	247	247	247	247	247	247	247	247	247	247
N_2O 5% [t/a]	176	176	176	176	176	176	176	176	176	176	176	176	176	176	176
N_2O 3% [t/a]	106	106	106	106	106	106	106	106	106	106	106	106	106	106	106

Table 73: Uncertainty for time-series trend for N_2O emissions from explosives use

Jahr	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Umax [%]	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%
Umin [%]	-40%	-40%	-40%	-40%	-40%	-40%	-40%	-40%	-40%	-40%	-40%	-40%	-40%	-40%	-40%

5.2.2.4 Source-specific quality assurance / control and verification (3.D)

For reporting, a general QC (Tier 1) was carried out, for the first time ever, in conformance with the requirements of the QSE manual and its applicable accompanying documents. The data for this source category was collected by an external expert, on behalf of the Federal Environmental Agency. Quality control was carried out by the external expert.

Nearly no data has been published relative to determination of N_2O emissions from explosives use. An experts' assessment was carried out this year relative to the emission factors. If the quality of the emission factors is to be improved, emissions and usage data for each type of explosive will be required.

5.2.2.5 Source-specific recalculations (3.D)

It has not yet been possible to carry out source-specific recalculations, since this source category is a new addition.

5.2.2.6 Planned improvements (source-specific) (3.D)

No improvements are planned at present.

6 AGRICULTURE (CRF SECTOR 4)

Source-category description

Emissions are assigned to the relevant emissions sources in accordance with the reporting categories CRF (Common Reporting Format, IPCC) and NFR (Nomenclature for Reporting, UNECE / EMEP).

Source category 4 in Germany includes Enteric fermentation (4.A), Manure management (4.B) and Agricultural soils (4.D).

Emissions from rice cultivation (4.C) do not occur in Germany, while Clearance of land by prescribed burning (4.E) is not practiced in Germany (NO). Field burning of agricultural residues (4.F) is prohibited in Germany, although it must be noted that some exemptions are permitted, and these do not lend themselves to surveys. Such exemptions are considered to be irrelevant (NO).

The German inventories for the gases methane (CH_4), non-methane volatile organic compounds (NMVOC), carbon dioxide (CO_2), ammonia (NH_3), nitrous oxide (N_2O) and nitrogen monoxide (NO) from agricultural sources have been prepared with the help of the relevant manuals (UN ECE: EMEP, 2003; IPCC Guidelines: IPCC, 1996b; IPCC Good Practice Guidance: IPCC-GPG, 2000) as well as with the help of other substantiated sources. Dinitrogen (N_2) emissions levels have to be known before the N amounts added to the soil can be calculated – i.e. before relevant indirect emissions can be determined. While these emissions have been calculated, they are not reported.

CO_2 emissions from agricultural soils, as a result of fertiliser use (liming) have been calculated using the data records described in this chapter, and they are reported under CRF 5.D (cf. Chapter 7.4).

Origins of the activity data

Activity data is taken from official German agricultural statistics, in keeping with availability. Every other year, results of the complete animal census for German districts are available. For the years in between, only animal head counts for the various Länder are available. The animal censuses cover all cattle, pigs, horses and sheep and all poultry. The data from the next-to-last animal census (2001) is available, and it has a spatial resolution at the rural district level. For reasons of data protection, the relevant data records are incomplete. Highly resolved data for 2003 is not yet available.

German agricultural statistics do not include herd-size figures for goats, mules and asses, fur-bearing animals and buffalo. Some indications as to the sizes of the relevant herds are available, however. The Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) estimates numbers of goats kept. These figures are used for the inventory. As to mules and asses, about 6,000 to 8,000 asses, and about 500 mules, are kept in Germany (DÄMMGEN et al., 2006). The pertinent emissions are considered negligible (NE). Official animal censuses do not include all horses, and thus the pertinent figures for horses are likely to be too low. They have been corrected in part (DÄMMGEN, 2005). The figures for sheep have to be corrected for some years (cf. DÄMMGEN, 2005). As to animals raised for fur, the Federal Ministry of Food, Agriculture and Consumer Protection (BMVEL) obtained the pertinent figures for calculation of NH_3 emissions from the Länder, in one instance for 2000; in some cases, the figures are estimated. CH_4 and N_2O emissions are not quantified (NE) for fur-bearing animals (CRF category "Others"), due to a lack of suitable calculation procedures. The figures for buffalo were provided by the German buffalo association (Deutscher Büffel-Verband).

The herd-size figures used for calves and piglets diverge from the relevant aggregated figures in the official statistics.

Complete area-use data is gathered in Germany every four years. In the inventories, the area figures are used in the context of activity, area and harvest data. In addition, they serve as input data for modelling important parameters for describing animal-keeping methods and farm-fertiliser management (see below). The data from the last survey (2003) is not available in usable form (i.e. broken down to the district level). This data was not taken into account.

Origins of the variables determining the emission factors

A number of important figures needed for emissions calculation pursuant to a Tier-2 method are not available in official statistics. Such figures were taken from the open literature, from association publications and from regulations for agricultural consulting in Germany.

Models have been prepared for important parameters relative to keeping of animals, storage of farm manure and spreading of such manure. The initial data for these models was collected via surveys and obtained from special evaluations of statistical data.

The calculation methods and provision of activity data are described in detail in DÄMMGEN et al. (2005).

6.1 Enteric fermentation (4.A)

In the area of animal husbandry, CH_4 emissions from enteric fermentation (4.A) must be reported. Microbial conversion in stomachs of ruminants – especially conversion of cellulose – releases CH_4. The quantities released per animal and unit of time depend on the animal species in question, individual-animal efficiency and feed composition.

In the CSE, source category 4.A Enteric fermentation is divided into the main sub-categories of cattle, sheep and goats, horses, mules and asses, swine and buffalo. Germany subdivides the main categories of cattle, swine and horses into sub- source categories (see Table 75).

Category CRF 4.A "Cattle" consists of the sub-categories "dairy cows" and the aggregated head counts for other cattle ("other cattle"). The group of "other cattle" includes calves, heifers, fattening bulls, mother cows and breeding bulls.

The source category "Horses" (CRF 4.A.6) is sub-divided into large horses and small horses. No figures for mules and asses are reported.

The German inventory divides source category CRF 4.A.8 "Swine" into sows, piglets, fattening pigs and boars.

Emissions from enteric fermentation in the poultry sector are not calculated, since no method for such calculation is known (NA).

In some cases, the animal head counts listed in official statistics cannot be directly allocated to sub- source categories. Allocations are described in detail in DÄMMGEN et al. (2006).

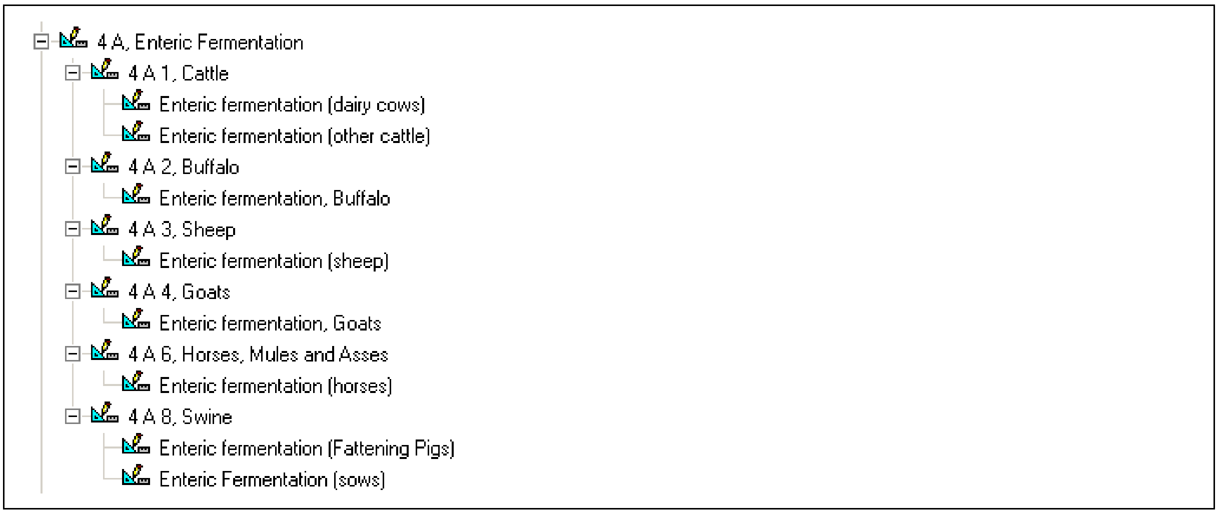


Figure 42: Structural allocation, 4.A Enteric fermentation

6.1.1 Source-category description (4.A)

CRF 4.A					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990- contribution to total emissions**	**2004- contribution to total emissions**	**Trend**
Enteric fermentation, dairy cows (CRF 4.A.1.a)	l / -	CH_4	1,00 %	0,96 %	falling
Enteric fermentation, other cattle (CRF 4.A.1.b)	l / t	CH_4	0,81 %	0,68 %	falling

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	NO	CS/C/D/ T1	NO	NO	NO	NO	NO	NO	NO	NO
EF uncertainties in %		30								
Distribution of uncertainties		L								
Method of EF determination		CS/C/D/ T1								

Within the source category "Enteric fermentation" (4.A), the sub- source category "dairy cows" (4.A.1.a) is a key category in terms of emissions levels; the sub- source category "other cattle" (4.A.1.b) is a key category in terms of emissions levels and trend.

Germany reports on the emissions of methane (CH_4) from enteric fermentation in the stomachs of dairy cows, other cattle (calves, bulls, heifers, mother cows, breeding bulls), swine, sheep, goats, horses and buffalo. Methods are lacking for treating poultry in this context (NA); in accordance with the IPCC (IPCC, 1996b, Chapter 4, Tab. A-4), the relevant quantities are considered negligible and are not calculated (not occurring). (NO).

6.1.1.1 Calculated emissions

A chronology of total emissions is presented in Table 74, while Figure 43 breaks down the emissions by animal species.

In Germany, almost all CH_4 emissions from enteric fermentation come from keeping of cattle (2004: 93 %). The pertinent shares from keeping of swine are small (2004: 3 %), and those for all other animals are small enough to be neglected. Dairy cows are the most important source category within the cattle category. The emissions reduction seen since 1990 (in conjunction with increasing emission factors for dairy cows and constant emission factors for all other animals) is a result of decreases in the numbers of animals kept. These decreases, in turn, can be explained as the result of changing dietary patterns on the part of consumers, as well as of increases in yields per individual animal (milk production, weight gains). The emissions are calculated for individual rural districts. Aggregated data on CH_4 emissions (national and at the Länder level) is provided by LÜTTICH et al, 2005.

Table 74: CH_4 emissions E_{CH4} from animal husbandry (enteric fermentation).

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[Tg a^{-1} CH_4]														
E_{CH4}	1,16	1,03	1,00	1,00	1,00	1,00	0,99	0,96	0,95	0,95	0,94	0,95	0,92	0,91	0,88

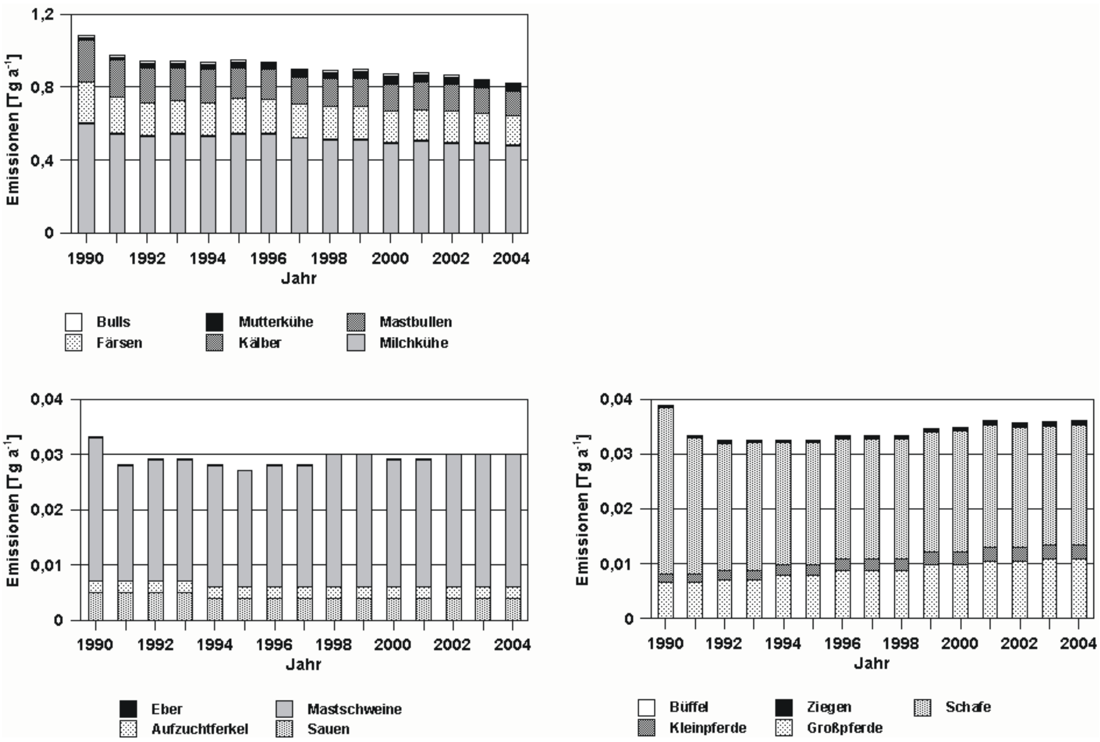


Figure 43: Time series for CH_4 emissions ECH_4 (enteric fermentation) for the animal categories considered.[44]

6.1.2 *Methodological issues (4.A)*

For determination of emissions from enteric fermentation, two different detailed methods are proposed: a simple method, with constant emission factors based on internationally accepted estimates (Tier-1 procedure), and a method that reflects the emissions process and that leads to variable emission factors (that depend on place and time) (Tier-2 procedure).

In principle, in both methods the emissions are calculated via the following steps:

- Determination with regard to properties and to emissions of homogeneous livestock herds (animal categories, sub- source categories)
- Determination of activity data, i.e. of the relevant numbers of animals involved, by animal type (main category) and by sub-categories based on age, sex and weight
- Determination of emission factors for each relevant category
- Calculation of total emissions

[44] Above left: cattle; below left: swine; below right: horses, sheep, goats and buffalo

IPCC-GPG (2000) calls for the more detailed Tier 2 method to be used in cases in which a country has listed methane emissions from animal husbandry as a key category for its inventories.

The Tier-2 method requires differentiated characterisation of livestock herds. Where a sub-category contributes significantly to digestion-related methane emissions, the emissions must be determined pursuant to a Tier-2 method. This means that a country-specific or region-specific, time-independent emission factor for the animals in question must be determined from suitably variable gross-energy intake, in accordance with the following equation:

Equation 4: Determination of specific emission factors

$$EF_i = \frac{GE \cdot x_m \cdot \alpha}{\eta_{CH4}}$$

where EF_i Emission factor for each sub-category i [%]
GE Gross energy intake [MJ animal^{-1} d^{-1}]
x_m Methane-conversion rate (percentage of gross energy that is converted to methane) [MJ MJ^{-1}])
α Conversion factor (365 d a^{-1})
η_{CH4} Energy content of methane (55.65 MJ (kg CH_4)$^{-1}$)

The gross energy intake is calculated using the *Detailed characterisation of livestock herds* and the methane-conversion rate from the IPCC-GPG (2000: Table 4-8) and from national data. Since the methane-conversion rate x_m (IPCC: Y_m) is an important factor in this equation, it should also be differentiated by animal species, age/weight and feed. The relevant values are given in IPCC (1996). National values were used for calves.

Total emissions are then determined as follows:

Equation 5: Complete emissions from the "Enteric fermentation" source category

$$E_{CH4} = \beta \cdot \sum EF_i \cdot n_i$$

where: E_{CH4} Methane emissions [Gg a^{-1}]
EF_{iCH4}, Emission factor for each sub-category i [kg animal^{-1} a^{-1}]
n_i Population size for each sub-category i [number of animals]
β Conversion factor [10^6 kg Gg^{-1}]

In analysis of key categories in agriculture, CH_4 emissions from dairy cows and other cattle in category 4 A, "Enteric fermentation", were identified as key categories. This creates a need for differentiated characterisation of livestock herds.

The procedure for calculation of emissions from farm-fertiliser management, with the help of a Tier-2 method, requires detailed calculation of input data (in the present context, excretion of volatile solids, VS, and of nitrogen). Since emissions from farm-fertiliser management in connection with swine are a key category, emissions from enteric fermentation for this animal category must also be calculated in accordance with the Tier-2 method.

6.1.2.1 Characterisation of animal stocks

The total animal population is divided into main and sub-categories for which activity data and emission factors are available. Disaggregation is carried out only where emission factors differ significantly. The following table compares the German sub-categories and the IPCC proposals.

Table 75: Detailed characterisation of animal herds pursuant to IPCC, and the breakdown used for Germany

	IPCC main categories	IPCC sub-categories	Germany (Deutschland)
Cattle	Dairy cows	Subdivision into two or more yield classes	Dairy cows, yield-/feed-oriented survey for each rural district
	Adult cattle, "other"	Male/female fattening and additions	Mother cows, breeding bulls
	Young animals	Heifers, calves, young male cattle	Calves, male and female young cattle (heifers and breeding bulls)
Swine	Sows	Pregnant sows Farrowing sows	Sows (including suckling piglets)
	Boars	---	Boars
	Young animals	Suckling piglets Growing young animals Slaughter-ready animals	Aufzuchtferkel, Mastschweine
Sheep	Ewes	Pregnant ewes Dairy sheep	Sheep, ewes, lambs
	Sheep >1 year	---	
	Young animals	Male animals, castrated animals, female animals	
Other	Horses, poultry, goats, donkeys, mules, camels, fur-bearing animals, etc.	---	Horses (large and small), poultry (laying hens, fattening cocks and hens), young hens, geese, ducks, turkeys), goats, fur-bearing animals, buffalo

Columns 1 and 2 pursuant to IPCC (2000)

6.1.2.1.1 *Numbers of animals*

The main basis for the activity data consists of the animal censuses of 1990, 1992, 1994, 1996, 1999, 2001 and 2003. The herd figures were not interpolated to permit description of years without herd-size statistics; instead, the herd figures were assumed to remain constant (LÜTTICH et al., 2005). The gaps in the new German Länder data for the years 1990 to 1993 were closed by means of experts' assessments.

6.1.2.1.2 *Dairy cows*

In the category of dairy cows, the official statistics provide information about slaughter weights; pertinent weights of living animals can be derived from these figures. Figures for milk production are taken from public district-level statistics. The relevant associations publish milk-fat and milk-protein data (with spatial resolution at the Länder level). The important variables relative to keeping of dairy cows (in the present context, duration of grazing) were modelled on the basis of data outside of official statistics (surveys and special evaluations).

6.1.2.1.3 *Other cattle*

In the cattle category, the types of animals differentiated – in addition to dairy cows – include calves, male and female fattening animals (heifers and fattening bulls), mother cows and breeding bulls. The slaughter weights of the various types of cattle are taken from official statistics and converted to weights of living animals. For breeding bulls, constant weights have been taken from the literature. Details on feeding and yields were taken from standard works on agriculture and discussed with experts. All other variables were modelled, as was done for dairy cows. The animals listed under "female fattening animals" are used either for herd supplementation and rejuvenation or for slaughter, depending on the market situation. Cattle used to supplement and rejuvenate herds and animals destined for slaughter do not differ in terms of the feed they are given and the conditions under which they are kept.

The herd characterisations, in terms of ages and weights, as used in animal censuses do not correspond to available data on energy balances and feeding. Only about half of the calves listed in animal censuses are treated as calves for purposes of the inventory. The other half is divided among the categories of heifers and fattening bulls.

6.1.2.1.4 Swine

The following categories are differentiated in the "swine" category: sows, piglets, fattening pigs and boars. The necessary details for relevant description were obtained from breeder associations and from the feedstuff industry. The lacking data for the new German Länder for the period after 1990 was obtained via discussions with experts.

6.1.2.1.5 Horses

The applicable number of horses was corrected, to account for special features of German animal censuses (Dämmgen, 2006). This correction takes account of the division made between large horses and small horses. Large horses and small horses differ in terms of their energy and feed requirements. The circumstances typical for Germany were derived from the literature and then used (see DÄMMGEN et al., 2006).

6.1.2.1.6 Sheep

The applicable numbers of sheep had to be corrected (DÄMMGEN, 2006). In addition, it was necessary to differentiate between lambs and other sheep.

6.1.2.1.7 All other animals

Further sub-grouping is not required for all other animals for which calculations are carried out in accordance with the Tier -1 approach. There are no default emission factors for sub-categories. What is more, it is not useful to use such factors in cases in which the relevant national data is not available. Detailed data on animal herds (national and at the Länder level), as well as additional information, is provided by LÜTTICH et al (2005).

6.1.2.2 Calculation of CH_4 emissions from keeping of dairy cows

The emission factor is determined by means of the approach proposed in IPCC (1996b). The relevant body weight is calculated on the basis of slaughter-weight (carcass) data (resolution: Länder and years). The maintenance energy is calculated using the constant factor that is normally used in Germany. The energy for feed intake can be derived from time spent grazing (resolution: Länder and years). Milk-yield data is available for (nearly) every district and every year. Data on milk-fat concentrations is taken from reports of the relevant associations (resolution: Länder and years). For dairy cows, it is assumed that weight gains during this period of the cows' lives can be neglected. Digestibility has been formulated as a function of yield, under a typical feeding framework (national data; resolution: districts and years).

The average milk yield for Germany, weighted by Länder and oriented to the base year 1990, is 12.9 kg animal^{-1} d^{-1}, which differs slightly from the IPCC's suggested value for western

Europe, 11.5 kg animal^{-1} d^{-1} (IPCC, 1996b: Table A-1). For 2004, the corresponding value is 18.0 kg animal^{-1} d^{-1}. The pertinent difference is significant. A compilation of all relevant information is provided by LÜTTICH et al. (2006).

The CH_4 emission factors in Germany range between 77 kg animal^{-1} a^{-1} CH_4 (1990) and 116 kg animal^{-1} a^{-1} CH_4 (2004); the national averages are 94.8 kg animal^{-1} a^{-1} CH_4 (1990) and 111.7 kg animal^{-1} a^{-1} CH_4 (2004). A detailed overview of the emission factors used is found in LÜTTICH et al. (2006). The manner in which the factors were obtained is described in DÄMMGEN et al., 2006).

6.1.2.3 Calculation of CH_4 emissions from keeping of other cattle (calves, heifers, fattening bulls, mother cows, breeding bulls)

To calculate the energy and feed requirements of growing animals, one requires certain figures pertaining to the life phase in question (initial and final weight, weight gain, duration of the life phase in question). Such figures are obtained, or derived, from slaughter statistics, publications of the Committee for Requirement Standards (Ausschuss für Bedarfsnormen) of the Society of Nutrition Physiology (Gesellschaft für Ernährungsphysiologie) and standard works on agricultural planning. In cases in which no national data was available, the default values pursuant to IPCC (1996b) were used. The fact that nursing calves are not ruminants was taken into account in calculations. A suitably lower methane-conversion rate was chosen. With regard to the factors determining the emission factors, and to the resulting emission factors, see LÜTTICH et al. (2006); for details on derivation of the emission factors, see DÄMMGEN et al. (2006).

Emissions from keeping of mother cows and breeding bulls are calculated from energy requirements, in keeping with the Tier-2 method, and under the assumption that weights remain constant.

The following mean emission factors for the year 2004 resulted:

Table 76: CH_4 emission factors IEF_{CH4} from keeping of cattle, with the exception of dairy cows (enteric fermentation) (2004)

Sub-category	EF_{CH4} [kg place^{-1} a^{-1} CH_4]
Calves	3,8
Heifers	33,5
Fattening bulls	53,8
Breeding bulls	56,7
Average	38,5
IPCC default	48

6.1.2.4 Calculation of CH_4 emissions from enteric fermentation in sows and growing swine (piglets, fattening pigs) and boars

To calculate emissions from sows, one must know the number and weight of relevant raised piglets. Such information is obtained from breeders' associations and from experts. The energy and feed requirements of growing animals is determined by the applicable initial and final weights, weight gain and duration of the relevant life phase. Such figures are obtained, or derived, from publications of the Committee for Requirement Standards (Ausschuss für Bedarfsnormen) of the Society of Nutrition Physiology (Gesellschaft für Ernährungsphysiologie), from breeders' associations and from standard works on agricultural planning.

For the purposes of the present inventory, the numbers of piglets given by the statistics are broken down into the categories of suckling piglets and piglets. Suckling piglets are included together with sows, while calculations for piglets are carried out separately.

As a result of Germany's special situation directly after 1990, many statistics were not collected. For example, very little or no detailed information was available on keeping of swine in the new German Länder between 1990 and 1996. That data was obtained from discussions with experts. At the end of the process, then, complete national data was available. This data is provided in the overview in LÜTTICH et al. (2006), while the calculations of numbers of animals, and the manner in which pertinent methods were derived or adjusted, are presented in DÄMMGEN et al. (2006).

Emissions from keeping of boars were calculated from energy requirements, under the assumption of a constant weight of 120 kg animal^{-1}.

The data resulting for 2004 is shown in the following table.

Table 77: CH_4 emission factors IEF_{CH4} from keeping of swine (enteric fermentation) (2004)

Sub-category	IEF_{CH4} [kg place^{-1} a^{-1} CH_4]
Sows	1,7
Piglets	0,41
Fattening swine	1,4
Breeding boars	1,5
Average	1,3
IPCC default	1,5

6.1.2.5 Calculation of CH_4 emissions from all other mammals (sheep, goats, horses, buffalo)

For all other mammals, the Tier-1 approach was used, as follows:

Equation 6: Tier-1 method for determining emissions from source category "Enteric fermentation"

$$E_{CH4,i} = EF_i \cdot n_i$$

where
- $E_{CH4,i}$ CH_4 emissions for a category [kg a^{-1} CH_4]
- i Animal category
- EF_i Emission factor for a category i [kg animal^{-1} a^{-1} CH_4]
- n_i Number of animals in a category i [animals]

For each animal species, the default values (emission factors) pursuant to IPCC (1996b: Chapter 4) were used:

Table 78: Emission factors: Default values (EF_d) pursuant to IPCC, and the resulting emission factors (*IEF*) used in this report

Animal category	EF_d pursuant to IPCC (1996b, Chap. 4) [kg animal^{-1} a^{-1} CH_4]	*IEF* after application of national data records [kg animal^{-1} a^{-1} CH_4]
Sheep	8 (Table 4-3)	
Goats	5 (Table 4-3)	
Horses	18 (Table 4-3)	16,4
Buffalo	55 (Table 4-3)	

For the reasons discussed above, Germany does not report emissions of mules and asses (NE).

6.1.3 Uncertainties and time-series consistency (4.A)

6.1.3.1 Relevant animal head counts

The uncertainties in the animal head counts in each class (with the exception of horses) are on the order of less than 6 % (DÄMMGEN, 2005). For the new *Länder*, herd sizes and their regional distribution for the years 1990 and 1991 were calculated using the RAUMIS model (HENRICHSMEYER et al., 1996), which provides regional data for agricultural production and products. As the data sources do not vary with the years, the time series is considered to be basically consistent.

The Agricultural Statistics Act (Agrarstatistikgesetz) was amended in 1998. This changed the survey bases for determining herd sizes – considerably, in some cases. Impacts were seen especially in numbers of horses and sheep. Therefore, correction factors were derived, to permit standardised description of the time series. Derivation of the corrections is described in DÄMMGEN (2006).

In all likelihood, the number of horses in Germany is about twice as large as the relevant figure from agricultural statistics, since many of the horses in question are not kept in agricultural operations (horses kept for recreational use). The head counts for horses are thus systematically erroneous.

With regard to sheep, the shift in the time series results in that the May count also includes lambs, while the December count does not.

6.1.3.2 Emission factors

The uncertainties in the methane emission factors are on the order of 30 % (EMEP, 2000: Chapter B1040-6). The primary sources of inaccuracy in these figures include the methane-conversion factor (for cattle, 0.06 ± 0.005, i.e. 10 %, cf. IPCC, 1996b) and the actual feed-ration composition, especially that for cattle.

6.1.4 Source-specific quality assurance / control and verification (4.A)

The data is reviewed for transcription errors made between the original data and the calculation tables, and it is checked for errors with regard to units and orders of magnitude. Future QC/QA will necessitate better resolution in the activity data (in particular, feeding data at the district level will be required). In addition, emission factors, except where confidential, will be made publicly available via the German Emission Factor Database (GEREF). This will enable experts to review and comment on the data.

Comparison to the mean emission factors (Implied Emission Factors) for neighbouring countries, as provided in the *Data Locator* of the UNFCCC Secretariat, shows that Germany lies within the middle section of the range.

Table 79: Methane emissions from enteric fermentation in dairy cows, in various countries – a comparison of Implied Emission Factors (IEF)[45]

Country	IEF_{CH4} (calculated EF) [kg animal^{-1} a^{-1} CH_4]
Austria	103
Czech Republic	68

[45] IEF: Emission factor calculated from emissions and numbers of dairy cows. Figures for D for 2004; data of other countries for 2003.

Denmark	118
Germany	*111,7*
France	103
Netherlands	82
United Kingdom	121

Source: CRF data for individual countries, for 2003

The inventory now, for the first time, lists errors or uncertainties for virtually all activity data, emission factors or other data used to calculate emission factors.

The agricultural section of the emissions inventory was reviewed in 2004 by Finnish experts, in the context of a bilateral review process. In the main, it was judged to be complete and in conformance with proper scientific practice (Lechtenböhmer et al., 2005). The in-country review carried out by UNFCCC (UNFCCC, 2005) reached the same result. The highlighted shortcomings (use of Tier-1 methods in calculation of emissions from keeping of cattle; lack of calculations for goats) have been eliminated in the present inventory.

6.1.5 Source-specific recalculations (4.A)

In most cases, the preliminary figures (animal head counts) for 2003 have been replaced with final figures. In the poultry category, the data on numbers of animals for 2000 through 2004, which had been obtained from model calculations in RAUMIS, was replaced with data from actual animal censuses.

For dairy cows, calves, heifers and fattening bulls, the Tier-2 method was used for the first time. This has eliminated the effects of a serious effort in data transfer. For the first time, reporting now also covers breeding bulls. This has caused some changes in emission factors (cf. Table 78 and Table 79).

Table 80: Comparison of the mean CH_4 emission factors used in the NIR 2005 and NIR 2006 for animal husbandry (enteric fermentation); here, dairy cows.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[kg animal^{-1} a^{-1} CH_4]														
NIR 2005	94,3	94,6	96,3	97,1	97,2	98,2	98,7	99,1	99,8	101,0	101,9	102,7	102,9	103,0	
NIR 2006	94,8	95,7	99,1	101,6	101,3	102,3	103,3	103,3	104,9	106,6	108,1	110,1	109,9	111,6	111,7

Table 81: Comparison of the mean CH_4 emission factors used in the NIR 2005 and NIR 2006 for animal husbandry (enteric fermentation); here, other cattle.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[kg animal^{-1} a^{-1} CH_4]														
NIR 2005	72,6	73,1	72,9	72,8	73,0	73,0	73,2	73,6	74,0	73,1	73,2	73,3	73,4	73,5	
NIR 2006	37,5	37,7	38,1	38,4	38,5	38,3	38,1	38,0	38,2	38,4	38,8	39,2	38,9	38,8	38,5

The emissions calculations for enteric fermentation in swine were carried out with disaggregated figures, in keeping with the Tier-2 method. This made it necessary to take emissions-explaining variables into account. Changes in the emission factors resulted (Table 82).

Table 82: Comparison of the mean CH_4 emission factors used in the NIR 2005 and NIR 2006 for animal husbandry (enteric fermentation); here, swine.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[kg animal^{-1} a^{-1} CH_4]														
NIR 2005	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	
NIR 2006	1,19	1,17	1,19	1,20	1,22	1,23	1,24	1,25	1,26	1,26	1,26	1,26	1,27	1,27	1,27

The figures for emissions from enteric fermentation in horses were determined with inclusion of corrected head counts for large and small horses. The resulting emission factors, which thus now vary over time and by place, are shown in Table 83.

Table 83: Comparison of the mean CH_4 emission factors used in the NIR 2005 and NIR 2006 for animal husbandry (enteric fermentation); here, horses.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[kg animal^{-1} a^{-1} CH_4]														
NIR 2005	18	18	18	18	18	18	18	18	18	18	18	18	18	18	
NIR 2006	16,5	16,5	16,5	16,5	16,4	16,4	16,4	16,4	16,4	16,5	16,5	16,3	16,3	16,4	16,4

Overall, the resulting CH_4 emissions from enteric fermentation, for the past few years, are now considerably different. The relevant changes are shown in Table 84.

Table 84: Comparison of the total CH_4 emissions for animal husbandry (enteric fermentation) as calculated for the NIR 2005 and NIR 2006. Figures are for Germany.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[Tg a^{-1} CH_4]														
NIR 2005	1,63	1,44	1,38	1,35	1,36	1,36	1,35	1,32	1,30	1,29	1,26	1,28	1,23	1,20	
NIR 2006	1,16	1,03	1,00	1,00	1,00	1,00	0,99	0,96	0,95	0,95	0,94	0,95	0,92	0,91	0,88

6.1.6 Planned improvements (source-specific) (4.A)

The basis for the data outside of official statistics is unsatisfactory in some areas (for example, feed-ration composition). An attempt is to be made to establish a procedure, in Germany, via which such data could be obtained by expanding agricultural statistics or conducting surveys.

6.2 Manure management (4.B)

6.2.1 Source-category description (4.B)

CRF 4.B					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
	- / -				

Gas	CO_2	CH_4	HFC	PFC	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)	NO	C/D	NO	NO	NO	D	D	-	CS	NO
EF uncertainties in %		30				NE				
Distribution of uncertainties		-				NE				
Method of EF determination		C/D/T1				CS/C				

The source category "Manure management" (4.B) is not a key category.

CH_4 and NMVOC, and NH_3, N_2O, NO, and N_2, are released in storage of farm manure in stalls, on paved areas outside of stalls, in pastures and in storage facilities (in the narrower sense), and such emissions are also released when manure is spread. NMVOC emissions can also include sulphur-containing compounds. Emissions depend on a range of factors, including animal category, animal excretions (which depend on animal yield and diet), time spent in specific types of quarters (pastures, stalls, paved areas), species-specific behaviour, stall type, use of straw, type and duration of manure storage, time and place of manure spreading, method used to spread manure and ways in which manure is worked into the soil.

In the present inventory, Germany reports on emissions from management of manure of cattle, swine, sheep, goats, horses, buffalo, fur-bearing animals (only NH_3) and poultry, but not on emissions from management of mule and ass manure (NE).

In the CSE, source category 4.B "Manure management" is divided into the sub-categories shown in Figure 44.

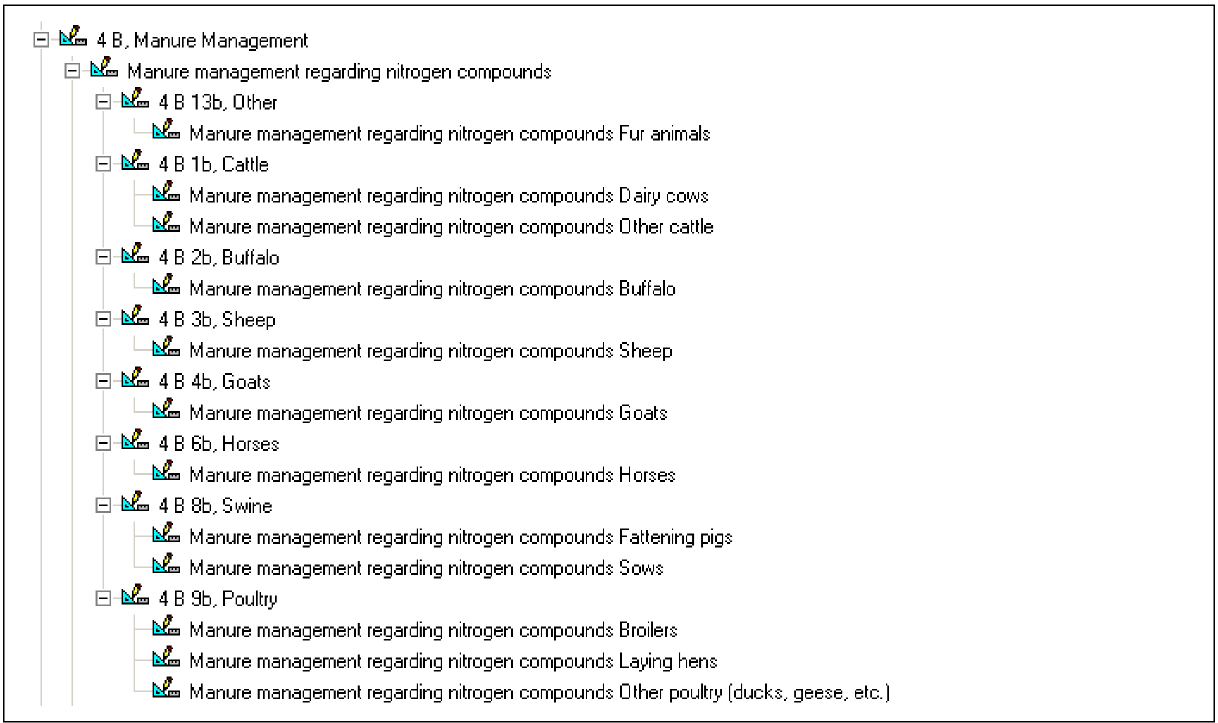


Figure 44: Structural allocation, 4.B Manure management

6.2.1.1 Methane emissions from manure management (4.B)

6.2.1.1.1 Calculated emissions

Table 85 presents the time series for CH_4 emissions from manure management. It shows an emissions decrease that is limited primarily to the years after German reunification and that points mainly to decreases in herd sizes (Figure 45). Of total emissions, cattle contribute two-thirds (63 % for 1990; 65 % for 2004) and swine contribute one-third (36 % for 1990; 30 % for 2004). As these figures indicate, emissions from keeping of poultry, and from keeping of horses, sheep, goats and buffalo, are negligible (cf. Figure 45).

Table 85: CH_4 emissions E_{CH4} from animal husbandry (manure management).

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[Tg a^{-1} CH_4.]														
E_{CH4}	0,29	0,26	0,25	0,25	0,27	0,26	0,27	0,26	0,26	0,27	0,26	0,26	0,26	0,26	0,25

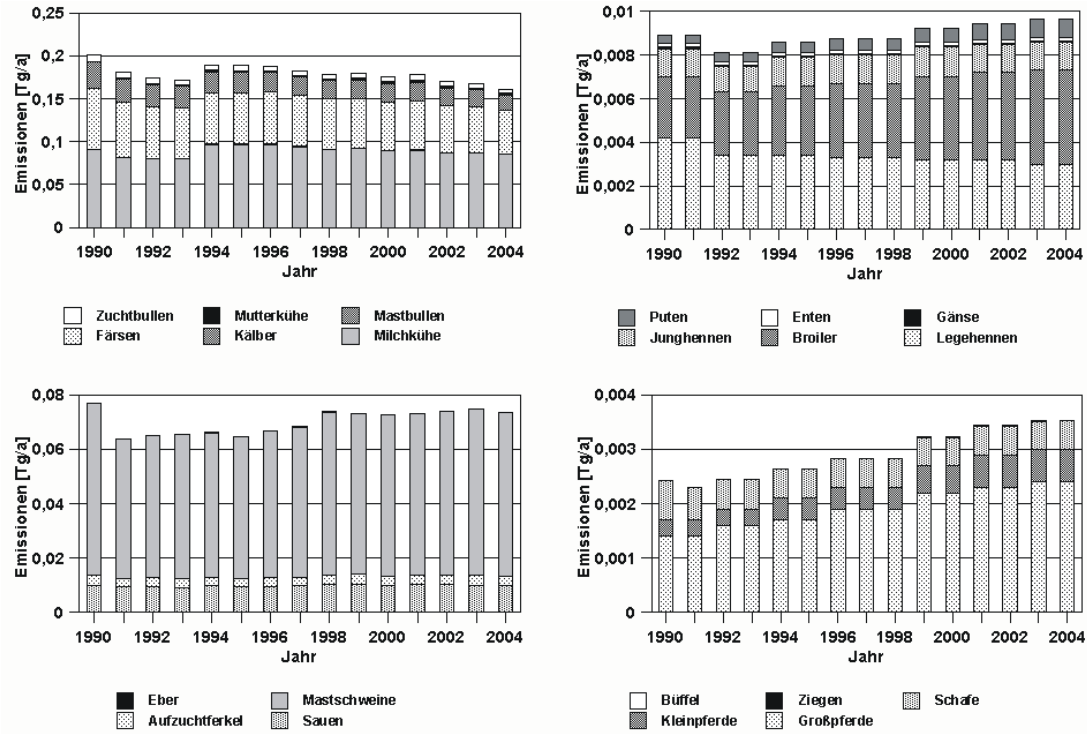


Figure 45: Time series for CH_4 emissions E_{CH4} for animal categories considered.[46]

6.2.1.2 NMVOC emissions from manure management

Microbial conversion of proteins in farm manure (about 50 % of the nitrogen contained in excretions is bound in proteins) produces both ammonia (NH_3) and non-methane volatile organic compounds (NMVOC). In the UK, the consistent proportionality seen between NH_3 emissions and NMVOC emissions from a range of different farm manures was used in preparation of a first NMVOC-emissions inventory. Germany has used that inventory's relative emission factors to prepare a first estimate of NMVOC emissions from animal husbandry (details in DÄMMGEN et al., 2006). The time series for NMVOC emissions is presented in Table 86, and the emitter composition is shown in Figure 46. Beginning in about 1994, following a decrease in animal-herd sizes, resulting from German reunification, emissions remained constant. Although no figures for horses are available, due to the lack of a relevant calculation procedure, their emissions can be assigned largely to "keeping of cattle".

[46] Above left: cattle; below left: swine; above right: poultry; below right: horses, sheep, goats and buffalo.

Table 86: NMVOC emissions E_{NMVOC} from animal husbandry (manure management), given as NMVOC and NMVOC-C.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[Tg a^{-1} C]														
E_{NMVOC}	0,33	0,29	0,28	0,28	0,26	0,26	0,26	0,26	0,26	0,26	0,25	0,26	0,25	0,25	0,25
$E_{NMVOC-C}$	0,21	0,18	0,18	0,18	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,16	0,16	0,16

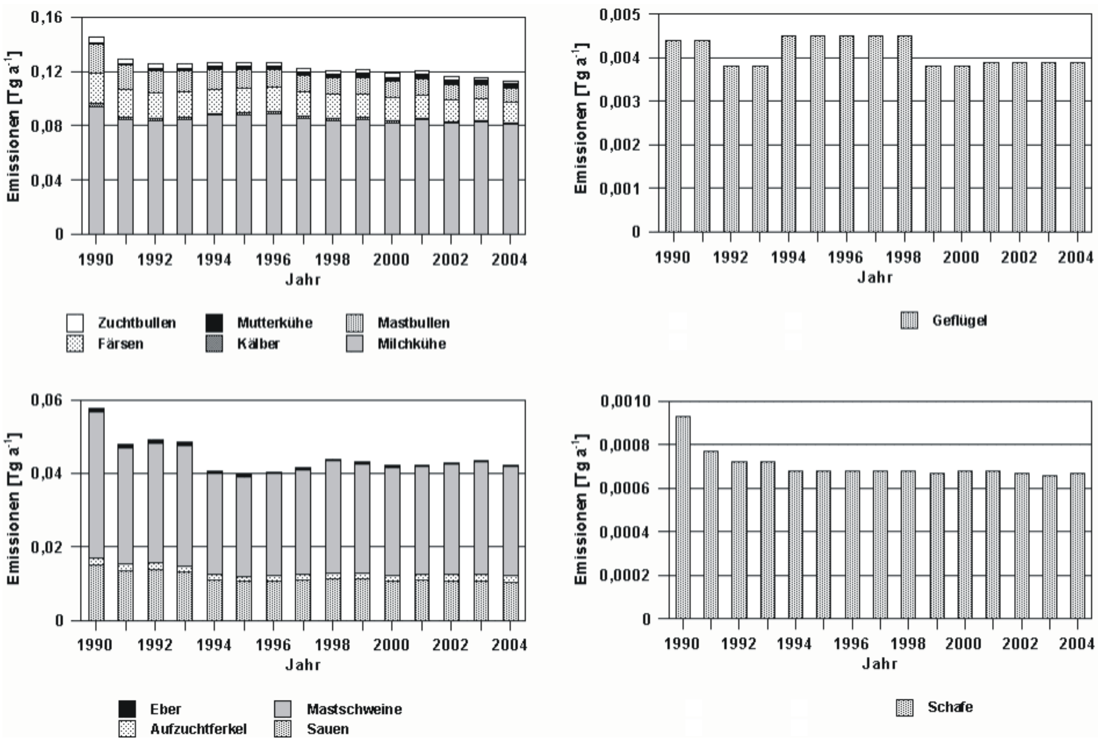


Figure 46: Time series of NMVOC-C emissions E_{NMVOC} (manure management) for the animal categories considered.[47]

In modelling of NMVOC emissions, it was also found that considerable amounts of dimethyl sulfide are emitted. Pursuant to these estimates, the emissions of sulphur bound in NMVOC amount to about 0.03 to 0.04 Tg a^{-1}. Additional discussion regarding the possible significance of these emissions for SO_2 concentrations and streams, for ecosystem acidification and for production of carbon oxide sulphide (COS), is presented in DÄMMGEN and KESSELMEIER (2006).

6.2.1.3 Nitrous oxide, nitrogen monoxide and ammonia emissions from manure management

The results of calculations of NH_3, N_2O and NO emissions are shown in Table 87; Figure 47 and Figure 48 present the results with reference to emitters. Since N_2O and NO emissions are proportional, NO emissions were not considered separately. N_2O and NO emissions have been decreasing considerably with regard to the base year. Cattle account for the major part of N_2O and NO emissions (66 % in 1990, and a decrease to 55 % in 2004). With respect to 1990, a total of 62 % of NH_3 emissions were emitted by cattle farms, 30 % were emitted by swine farms and 6 % were emitted by poultry operations. A total of 67 % of (direct) N_2O and NO emissions originate in keeping of cattle, while 17 % originate in keeping of swine and 10 % originate in keeping of poultry. In 2004, the respective shares for NH_3 were 61 %, 27 % and 10 %. The respective shares for N_2O and NO in 2004 were 55 %, 14 % and 21 %.

[47] Above left: cattle; below left: swine; above right: poultry; below left: sheep.

Table 87: N_2O, NO and NH_3 emissions E_{N2O}, E_{NO} and E_{NH3} from animal husbandry (manure management).

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[Gg a^{-1} N_2O, NO and NH_3]														
E_{N2O}	0,013	0,012	0,011	0,011	0,010	0,010	0,010	0,010	0,009	0,010	0,009	0,010	0,009	0,009	0,009
E_{NO}	0,018	0,016	0,016	0,015	0,013	0,013	0,013	0,013	0,013	0,013	0,013	0,013	0,013	0,013	0,013
E_{NH3}	0,61	0,54	0,53	0,52	0,51	0,51	0,51	0,50	0,50	0,50	0,49	0,50	0,49	0,49	0,48

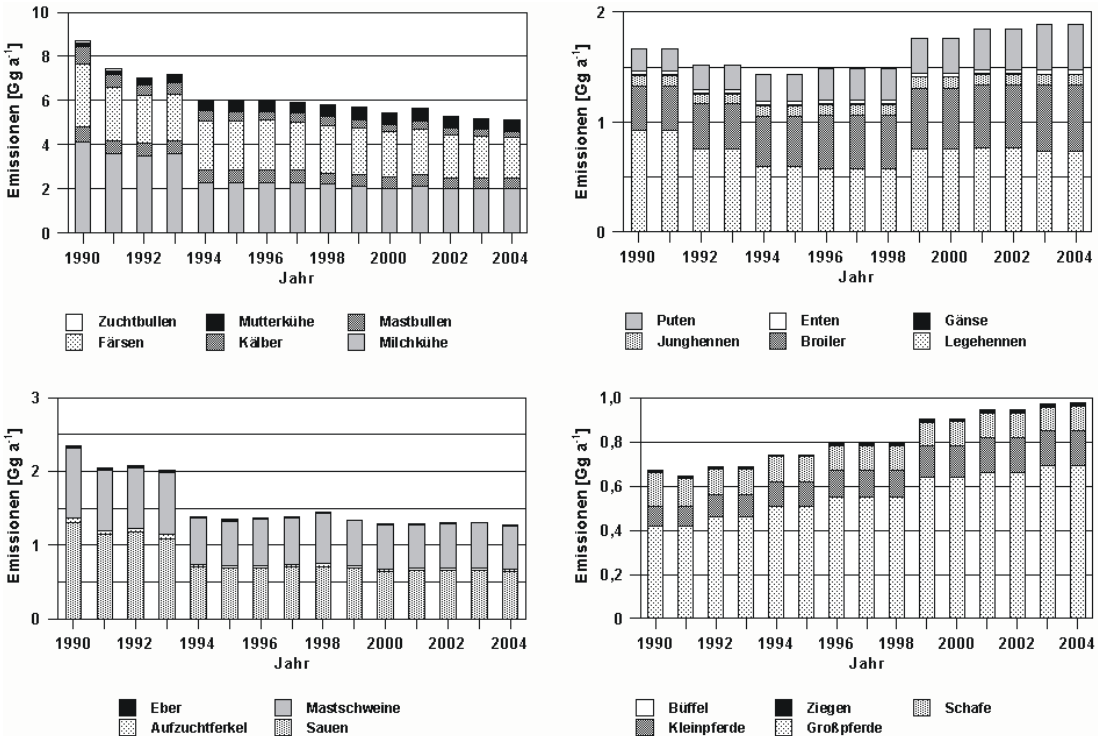
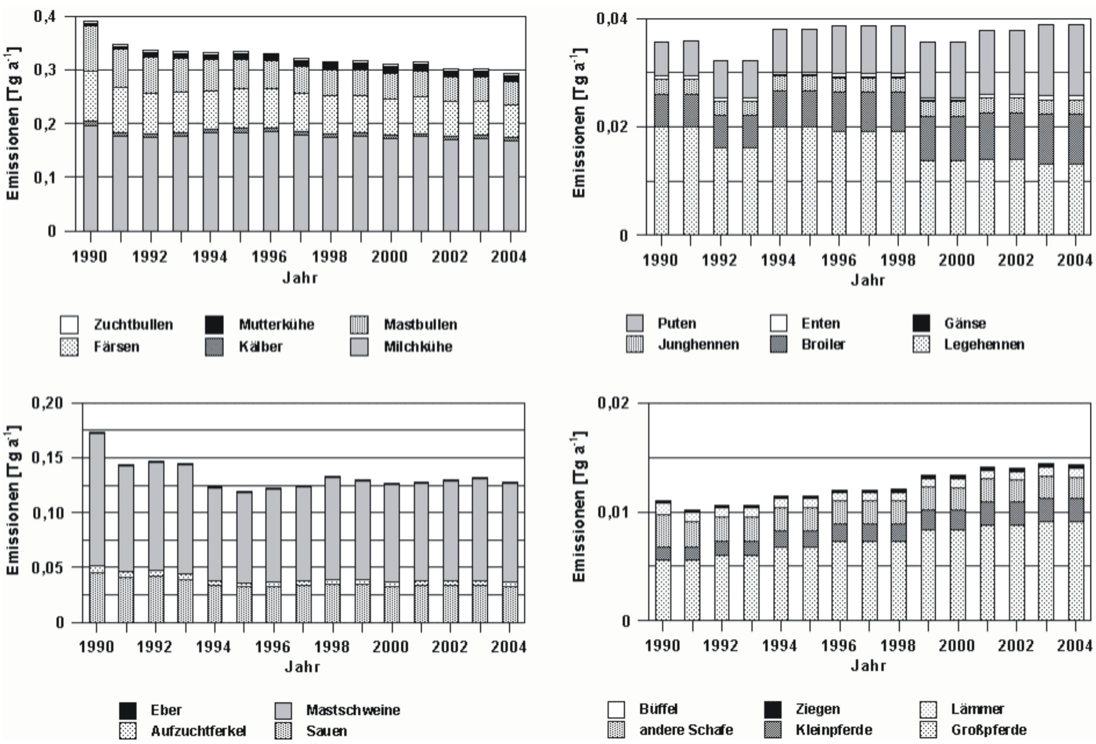


Figure 47: Time series for N_2O emissions E_{N2O} for animal categories considered.[48]



[48] Above left: cattle; below left: swine; above right: poultry; below right: horses and sheep.

Figure 48: Time series for NH_3 emissions E_{NH3} for animal categories considered.[49]

6.2.2 Methodological issues (4.B)

6.2.2.1 Methodological issues and requirements, CRF 4.B (CH_4)

IPCC (1996b) provides for two methods for determining CH_4 emissions from manure management. For emissions calculation pursuant to the Tier-1 method, numbers of animals are multiplied by constant VS excretions[50] and by default emission factors that are constant for specific climate regions.

This Tier-1 method is not used in its simple form.

The Tier-2 method calls for consideration of variable VS excretions that depend on yields and diet. Furthermore, the method combines these with emission factors that reflect the frequency of various procedures for storage of solid and liquid manure in Germany, and that take climate effects into account. The resulting emission factors then vary for each category, by place and time. The emission factor is determined via the following equation:

Equation 7: Determination of the emission factor for methane from manure management, pursuant to the Tier-2 method

$$EF_i = VS_i \cdot \alpha \cdot B_{oi} \cdot \rho_{CH4} \cdot \sum_{jk} MCF_{jk} \cdot MS_{ijk}$$

where
- EF_i Emission factor for each sub-category i [kg animal^{-1} a^{-1} CH_4]
- α Time conversion (α= 365 d a^{-1})
- VS Volatile solids (excretion of readily decomposable material, dry mass - DM) for the sub-category i [kg animal^{-1} d^{-1} DM]
- B_{oi} Methane-formation potential with regard to VS [m^3 kg^{-1}]
- ρ_{CH4} Methane density (ρ_{CH4} = 0.67 kg m^{-3})
- MCF Methane-conversion factor for storage system j in climate region k [kg kg^{-1}]
- MS Share of sub-category whose farm manure is treated in storage system j

In the German inventory report, CH_4 emissions from management of manure from dairy cows, cattle and swine have been classified as a key category (for details, see Chapter 6.2.1). The calculations are carried out for rural districts (DÄMMGEN et al., 2006)

Mixed procedures that combine elements of the Tier-1 and Tier-2 methods (UNECE: improved procedures) use default values for VS excretions and combine them with the frequency distributions for manure-management systems in the relevant region. In Germany, this applies to sheep, goats, horses, buffalo and poultry.

6.2.2.2 Methodological issues and requirements, CRF 4 B (N_2O, NO and N_2)

Since 2004, the mass-flow procedure pursuant to EMEP/CORINAIR has been used to calculate losses of gaseous N species (cf. DÄMMGEN et al., 2006). It considers *all* flows of N species, both in succession and in parallel, in keeping with the scheme shown in Figure 49.

[49] Above left: cattle; below left: swine; above right: poultry; below right: horses, sheep, goats and buffalo.
[50] VS (volatile solids): the easily convertible carbon fractions in excrement

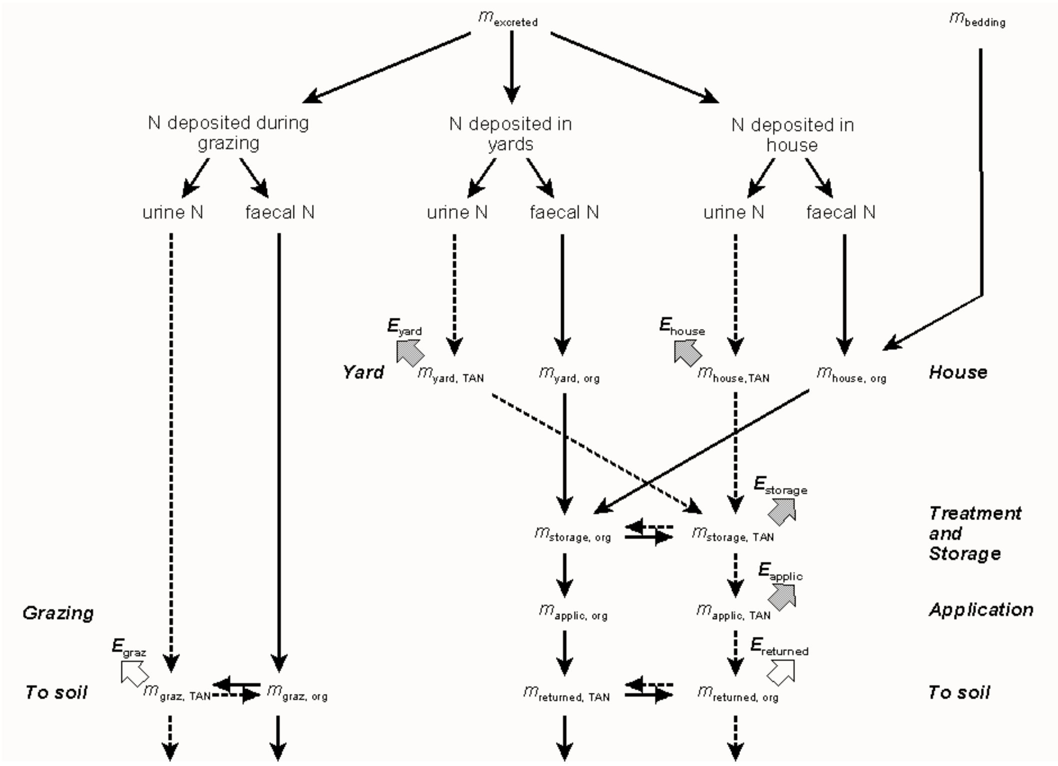


Figure 49: Nitrogen flows in manure management for a given category.[51]

The first step is to determine the amounts of excreted N and of TAN (total ammoniacal nitrogen). The latter of these is excreted in animals' urine. To take account of grazing periods and animals' behaviour, excretion amounts are divided into amounts in pastures and amounts in stalls. In the substance-flow model, and for cattle, the duration of grazing (pasture) periods, the average grazing duration per day and the average time spent in milking stalls are used to divide excrement into pasture and stall portions.

Emissions of all N species in pastures occur simultaneously. Calculations are carried out in accordance with IPCC (1996b) and EMEP (2006).

In stalls, TAN losses occur through NH_3 emissions. The N in the remaining TAN is the source of emissions of NH_3, N_2O, NO and N_2. In principle, the relevant emissions levels are a function of type of storage and of temperature.

Total N_2O emissions are determined pursuant to IPCC (2000), with the following equation:

Equation 8: Determination of N_2O emissions from manure management

$$E_{\mathrm{N2O-N}} = \sum_{\mathrm{i,j}} n_{\mathrm{i}} \cdot m_{\mathrm{ex,i}} \cdot x_{\mathrm{i,j}} \cdot EF_{\mathrm{j}}$$

[51] Solid lines: organically bound N; dotted lines: TAN;
the horizontal flows stand for immobilisation and mineralisation;
broad arrows refer to emissions:

E_{yard}:	NH_3 emissions from paved areas, including milking stalls;
E_{house}:	NH_3 emissions from stalls;
$E_{storage}$	NH_3, N_2O, NO and N_2 emissions from storage;
E_{applic}	NH_3 emissions during and after spreading;
E_{graz}:	NH_3, N_2O, NO and N_2 emissions during and after grazing;
$E_{returned}$	N_2O, NO and N_2 emissions from the soil (for details, see DÄMMGEN et al., 2006)

where E_{N2O-N} N_2O-N emissions from manure management
n_i Number of animals of category i
$m_{ex,i}$ Mean annual N excretions of category i
$x_{i,j}$ Percentage of the annual excretions of category i that is subject to a certain manure-management system j.
EF_j N_2O emission factor for manure-management system j

The N_2O emission factor given in IPCC (1996b) refers to the amount of N that is excreted or stored. Due to a lack of better relationships, here as well the N_2O emissions are set in relation to this amount, although they are subtracted from the remaining amount of TAN. A similar procedure is carried out for NO and N_2. During storage, part of the organically bound N (total N $\rightarrow$ TAN) is mineralised.

Losses during spreading are calculated solely for NH_3. They refer to the amount of TAN that is available following storage in farm manure. The relevant partial emission factors are taken from EMEP (2002b).

Pursuant to IPCC (2000), the parameters for the above formula must be obtained through statistical surveys and through measurements. In the process, framework conditions such as the effectiveness of the relevant surface, the ventilation situation and the temperature for manure storage must be taken into account. The entire data-collection, data-review and documentation process is, thus, considerably involved. Germany lacks pertinent data records. IPCC (2000) also contains default values for emission factors, however (Tables 4-12 and 4–13).

The emission factors (liquid-manure-based systems: $EF_{N2O} = EF_{NO} = 0.001$ kg kg^{-1} N, $EF_{N2} = 0.007$ kg kg^{-1} N; straw-based systems: $EF_{N2O} = EF_{NO} = 0.02$ kg kg^{-1} N, $EF_{N2} = 0.14$ kg kg^{-1} N) have either been taken from IPCC or derived from that source (IPCC, 1996b: Table 4-22). The quantities of N_2 that form simultaneously with N_2O are estimated on the basis of literature data, with a view to calculation of indirect emissions.

All of the stall categories commonly found in Germany are considered. Information on frequency distribution is provided by LÜTTICH et al. (2005).

The figures are determined for each rural district, with the help of the RAUMIS agricultural sector model (HEINRICHSMEYER et al., 1996). In principle, a different emission factor results each year for each animal category and each district (DÄMMGEN et al., 2006).

Pursuant to key-source analysis, category 4.B N_2O emissions are not a key category. For this reason, a simple method (Tier -1 approach) may be used for calculation. In such calculation, national data for N excretion is used (cf. Chapter 6.2.2.4).

6.2.2.3 Relevant animal head counts

Normally, emissions of N-containing compounds for a given animal category are calculated using the numbers of animals in the entire relevant population. The *cattle* category is subdivided into dairy cows, calves, fattening bulls, heifers, mother cows and breeding bulls. In the *swine* category, sows, piglets, fattening pigs and boars are treated separately. The emission factors for sows include emissions from suckling piglets. In the cattle and swine categories, the head counts from official statistics have to be converted to meet the mass-flow procedure's requirements relative to population homogeneity.

In the *sheep* category, N-species emissions are calculated from statistics – corrected to account for the amendment of the Agricultural Statistics Act (Agrarstatistikgesetz) – for lambs and other sheep. CH_4 emissions, on the other hand, are determined from the size of the entire sheep population (cf. DÄMMGEN, 2006).

Official animal censuses provide only incomplete head counts of horse populations. In addition, the relevant animal census data is corrected to compensate for impacts of the amendment of the Agricultural Statistics Act (Agrarstatistikgesetz) (cf. DÄMMGEN, 2006).

6.2.2.4 Excrement

C species:

In the cattle and swine categories, excretions of "volatile solids" are calculated in accordance with Tier-2 determinations of emissions from enteric fermentation. For all other animal species, the default values pursuant to IPCC (1996b: Tables B-1 and B-7) are used:

Sheep	0,40	kg animal^{-1} d^{-1} C
Goats	0,40	kg animal^{-1} d^{-1} C
Horses	1,72	kg animal^{-1} d^{-1} C
Poultry	0,10	kg animal^{-1} d^{-1} C
Buffalo	2,7	kg animal^{-1} d^{-1} C

NMVOC emissions are calculated via use of calculated quantities of NH_3 emissions, since the two substance groups are linked via their formation mechanism.

N species:

For dairy cows, N excretions are calculated as a function of milk yield, milk-protein levels, weight, number of births per year and raw-fodder composition. A detailed description of this procedure is provided by DÄMMGEN et al. (2006), while an assessment of the procedure is provided by DÄMMGEN and LÜTTICH (2006). This calculation procedure also yields the pertinent TAN excretions.

For swine, N excretions are determined from animal yields (for sows: number of piglets per year; for piglets and fattening pigs: weight gains) as well as from weights and fodder composition. Feeding data was used as a basis for calculations relative to boars.

For all other animals, N-excretion figures were taken from the German literature (DÄMMGEN et al., 2006). Specifically, the following figures were used:

Male beef cattle	42 kg animal^{-1} a^{-1} N
Female beef cattle	44 kg animal^{-1} a^{-1} N
Calves	16 kg animal^{-1} a^{-1} N
Mother cows	96 kg animal^{-1} a^{-1} N
Sheep	13 kg animal^{-1} a^{-1} N
Horses	64 kg animal^{-1} a^{-1} N
Laying hens	0.74 kg animal^{-1} a^{-1} N
phase-fed	0.71 kg animal^{-1} a^{-1} N
Fattened cocks and chickens	0.29 kg animal^{-1} a^{-1} N
Young hens	0.28 kg animal^{-1} a^{-1} N
Geese	0.73 kg animal^{-1} a^{-1} N
Ducks	0.60 kg animal^{-1} a^{-1} N
Turkeys	1.50 kg animal^{-1} a^{-1} N
phase-fed	1.41 kg animal^{-1} a^{-1} N
Buffalo	70 kg animal^{-1} a^{-1} N

For animals with lifetimes < 1 a, the figures for were calculated for keeping facilities with average rotation periods.

The percentage of total ammoniacal N (TAN) with respect to total nitrogen was calculated as follows:

Dairy cows	variable
Cattle, except for dairy cows	0.60 kg kg^{-1} N
Swine	0.70 kg kg^{-1} N
Sheep	0.40 kg kg^{-1} N
Horses	0.40 kg kg^{-1} N
Poultry	0.70 kg kg^{-1} N
Buffalo	0.50 kg kg^{-1} N

6.2.2.5 Grazing periods, stable types and stabling periods

In the cattle category, the duration of grazing (pasture) periods, the average grazing duration per day and the average time spent in milking stalls are used to divide excrement into pasture and stable portions.

All of the stable categories commonly found in Germany are taken into account (LÜTTICH et al., 2006). The relevant data is compiled in the CRF report tables 4 B(a) and 4 B(b) (additional information).

6.2.2.6 Processing of liquid and solid manure

A distinction should be made between processed and unprocessed manure (aspects to consider for example, include liquid-manure separation, biogas collection, composting of solid manure). As a result of a lack of pertinent background information about manure processing (frequency distributions), as well as of certain calculation procedures (for solid-manure composting), no suitably differentiated calculations can be carried out at present, however.

6.2.2.7 Storage

A distinction is made between solid and liquid manure. The storage forms commonly used in Germany are taken into account. Daily spreading is not commonly practiced in Germany; open lagoons are not used. CRF Table 4.B(b) lists the frequency distributions for the various forms of storage.

6.2.2.8 Spreading

The spreading method used, and the time of subsequent working of manure into the soil, play an important role in calculation of NH_3 emissions and in determination of the N quantities added to the soil via manure. For liquid manure, a distinction is made between broad distribution, towed tubes and towed "shoes"; for solid manure, only broad distribution is considered. Farmland (fallow and with vegetation) and grassland are differentiated. A graduated scale of periods required to work manure into the soil is used (< 1 h, < 4 h, < 6 h, < 12 h,< 24 h, no working into the soil).

6.2.3 Uncertainties and time-series consistency (4.B)

The uncertainties listed in the EMEP/CORINAIR manual (EMEP, 2003) also apply, for the time being, to Germany; i.e. about 6 % for animal head counts (cf. also DÄMMGEN, 2006) and 30 % for emission factors for CH_4 and NH_3. The errors for the other emission factors are not known. For N_2O, NO and N_2, the order of magnitude is probably accurate.

The time series from official statistics is inconsistent with regard to herd populations, due to amendment of the Agricultural Statistics Act (Agrarstatistikgesetz); i.e. a break occurs between 1998 and 1999. This applies especially to the categories of sheep and horses. A correction procedure for both categories has been developed and applied. As to horse head counts, it must be noted that agricultural censuses cover only part of the horses in question and that agricultural operations do not keep "recreational horses". With regard to sheep, the shift in the time series results in that the May count also includes lambs, while the December count does not.

The figures on manure management have been modelled on the basis of a database that is considered inadequate (transfer of survey data collected in model districts to other districts; cf. UBA, 2002a). As to uncertainties, only approximate (order-of-magnitude) information is available.

6.2.4 Source-specific quality assurance / control and verification (4.B)

The data is reviewed for transcription errors made between the original data and the calculation tables, and it is checked for errors with regard to units and orders of magnitude. Future QA/QC procedures pre-suppose the further development of methods and a better breakdown of activity data (cf. Chapter 6.1.4). In addition, better data is needed for description of manure management.

In particular, such data would include parameters for feeding, yields (slaughter weight, duration of fattening period, etc.), keeping method (with pasturing, type of stabling), type of storage, spreading methods, etc.. Such data must be obtained via surveys.

For the first time, the present inventory lists errors or uncertainties for virtually all activity data, emission factors or other data used to calculate emission factors. The total error arising from the individual errors in the terms of a complex emission function should be determined by means of an error-propagation calculation. Plans call for such calculation to be carried out in future.

The agricultural section of the emissions inventory was reviewed in 2004 by Finnish experts, in the context of a bilateral review process. In the main, it was judged to be complete and in conformance with proper scientific practice (LECHTENBÖHMER et al., 2005). The in-country review carried out by UNFCCC (UNFCCC, 2005) reached the same result. The highlighted shortcomings (use of Tier-1 methods in calculation of emissions from keeping of cattle and from keeping of swine; lack of calculations for goats) have been eliminated in the present inventory. The mass-flow procedure has been reviewed by the EAGER experts' group, and the results obtained in Europe have been compared. A summarising description with regard to cattle is provided by REIDY et al. (2006).

6.2.5 Source-specific recalculations (4.B)

6.2.5.1 Source-specific recalculations (CH_4)

In the poultry category, the number-of-animal figures used for 1990 through 1993, figures based on model calculations from RAUMIS, have been replaced with figures from animal censuses.

For the first time, the procedure for CH_4-emissions calculation for management of cattle and swine manure used results from the Tier-2 procedure for calculation of emissions from enteric fermentation. For sheep and horses, the time series for animal head counts were corrected. The main difference, however, has to do with use of the *MCF*, for liquid manure, from IPCC (1996b) (10 %) instead of the value from IPCC (2000), which listed 39 %. A detailed description of this procedure is provided by DÄMMGEN et al. (2006).

The pertinent differences are shown in the following table.

Table 88: Comparison of figures given in NIR 2005 for CH_4 emissions E_{CH4} from animal husbandry (manure management).

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[Tg a^{-1} CH_4]														
NIR 2005	1,29	1,12	1,09	1,07	1,16	1,13	1,14	1,18	1,13	1,14	1,11	1,12	1,10	1,10	
NIR 2006	0,29	0,26	0,25	0,25	0,27	0,26	0,27	0,26	0,26	0,27	0,26	0,26	0,26	0,26	0,25

6.2.5.2 Source-specific recalculations (NMVOC)

NMVOC emissions are calculated using the NH_3 emissions for the animal species in question. Since changes occurred in this area (see the following chapter), the NMVOC emissions also had to be recalculated.

Table 89: Comparison of figures given in NIR 2005 for NMVOC emissions E_{NMVOC} from animal husbandry (manure management).

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[Tg a^{-1} C]														
NIR 2005	0,30	0,27	0,26	0,26	0,24	0,24	0,24	0,24	0,24	0,24	0,23	0,23	0,23	0,23	
NIR 2006	0,21	0,18	0,18	0,18	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,16	0,16	0,16

6.2.5.3 Source-specific recalculations (NH_3, N_2O, NO, N_2)

For the categories of dairy cows, breeding bulls and swine, a new basis was used for calculation of N excretions. This made it necessary to recalculate emissions of all N species from animal husbandry.

Specifically, the following changes were made:

- A number of transcription errors were eliminated.
- The TAN levels in excretions of dairy cows are now calculated as a function of feeding and yield, while for all other cattle a value of 0.60 kg kg^{-1} N is used, in conformance with other inventories in north-western Europe.
- The present inventory uses a value of 0.70 kg kg^{-1} N, which is internationally customary and is justified for Germany, for the TAN level for swine. In the categories of fattening pigs and piglets, N excretions are now calculated as a function of yield and feeding. In the category of sows, the N-excretion figure – unlike that of earlier inventories – includes suckling piglets of up to 8.5 kg $animal^{-1}$. Boars are considered separately. As a result of yield-based consideration of swine excretions, the emission factors for piglets and fattening pigs in stalls were lowered to 0.30 kg kg^{-1} N for slatted floors with liquid manure and to 0.35 kg kg^{-1} N for relevant systems with straw. On the other hand, losses from uncovered liquid-manure storage facilities were assumed to be 15 % TAN, in conformance with other north-west European inventories. The amounts of straw used in straw-based systems were corrected, in part.

- For all straw-based systems, mineralisation of straw N, and immobilisation of TAN in connection with adequate straw use, were taken into account on the basis of new findings. The improved database led to a reduction in the relationship of N_2 to N_2O-N in the area of manure emissions from storage.
- Nitrogen excretions from fattening cocks and hens, and from turkeys, were brought into conformance with the most recent findings (fattening cocks and hens: 0.41 instead of 0.29 kg place^{-1} a^{-1} N; turkeys: 2.07 instead of 1.5 kg place^{-1} a^{-1} N).

For the first time, Germany is reporting emissions from keeping of goats and buffalo and taking account of emissions from imported farm manure.

This leads to changes in NH_3 and NO emissions, as the following tables show:

Table 90: Comparison of figures for N_2O emissions E_{N2O} from animal husbandry (manure management) given in the NIR 2005 and NIR 2006. Figures are for Germany.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[Gg a^{-1} N_2O]														
NIR 2005	134,4	12,8	12,5	12,4	10,1	10,1	10,2	10,1	10,0	9,8	9,7	9,8	9,6	9,4	
NIR 2006	13,3	11,8	11,4	11,3	9,5	9,5	9,6	9,5	9,5	9,6	9,5	9,6	9,4	9,4	9,2

Table 91: Comparison of figures for NO emissions E_{NO} from animal husbandry (manure management) given in the NIR 2005 and NIR 2006. Figures are for Germany.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[Gg a^{-1} NO]														
NIR 2005	19,7	17,4	17,0	16,8	13,8	13,8	14,0	13,8	13,7	13,4	13,2	13,3	13,1	12,9	
NIR 2006	18,2	16,0	15,5	15,4	13,0	13,0	13,2	13,0	12,9	13,1	12,9	13,1	12,8	12,8	12,5

Table 92: Comparison of figures for NH_3 emissions E_{NH3} from animal husbandry (manure management) given in the NIR 2005 and NIR 2006. Figures are for Germany.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[Tg a^{-1} NH_3]														
NIR 2005	0,58	0,51	0,50	0,50	0,47	0,47	0,47	0,47	0,47	0,46	0,45	0,46	0,45	0,45	
NIR 2006	0,61	0,54	0,53	0,52	0,51	0,51	0,51	0,50	0,50	0,50	0,49	0,50	0,49	0,49	0,48

6.2.6 Planned improvements (source-specific) (4.B)

Any updates of the database below official statistics require data from the 2003 main survey of soil use (Bodennutzungshaupterhebung). This data was not yet available for the present inventory. In addition, such updates require data from urgently needed surveys. The data collected last year is still incomplete, and it has to be interpreted in light of findings of the main survey of soil use (Bodennutzungshaupterhebung).

The mass-flow-model method and its parameters are being reviewed, expanded and harmonised via international cooperation.

6.3 Rice cultivation (4.C)

No rice is cultivated in Germany (NO).

6.4 Agricultural soils (4.D)

The source category "Agricultural soils" comprises direct and indirect emissions of nitrogen species (N_2O and NO) and CH_4 consumption by agricultural soils.

In the CSE, source category 4.D Agricultural soils includes crop cultivation with and without fertiliser use.

Figure 50: Structural allocation, 4.D Agricultural soils

6.4.1 Source-category description (4.D)

CRF 4.D					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
Agricultural soil, direct soil emissions (CRF 4.D.1)	l / t	N_2O	2,23 %	2,34 %	rising
Agricultural soil, indirect emissions (CRF 4.D.3)	l / -	N_2O	1,12 %	1,13 %	stag-nating

Gas	**CO_2**	**CH_4**	**HFC**	**PFC**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor (EF)	IE	CS	NO	NO	NO	C/D	C/D	NO	C	NO
EF uncertainties in %		50				50				
Distribution of uncertainties		-				-				
Method of EF determination		CS				C/CS				

With regard to N_2O, source category Agricultural soils (4.D) is a key category of direct and indirect emissions, in terms of emissions levels.

EMEP (2004) classifies agricultural soils as a key category for NH_3.

Microbial reactions (nitrification and denitrification) with nitrogen compounds lead to emissions of nitrous oxide. The more nitrogen that enters the soil, the higher can be the rates of nitrification and denitrification. For this reason, N-inputs play an important role in determination of N-species emissions. The extent of such reactions depend on a number of other soil parameters, however (water-filled pore space, temperature, C content), that are not covered by the IPCC methods. The improved EMEP procedure (EMEP, 2003) requires the use of detailed soil data that is currently not available.

Direct N-inputs leading to N_2O emissions include use of mineral and farm fertilisers, spreading of sewage sludge, legume cultivation, working of plant residues into the soil, inputs of animal excretions in pastures and N-mineralisation in cultivation of organic soils.

The inventory provides information about direct N_2O, NO and NH_3 emissions from these sources, to the extent pertinent methods have been described.

Indirect N_2O emissions from agriculture come from leaching and surface run-off from fertilised areas (including use of sewage sludges) as well as from atmospheric deposition of NH_3 and NO_x from agricultural sources.

In principle, plant stocks are always sources of volatile organic compounds. A first estimate of surch emissions was carried out for important crops.

Agricultural soils are sinks for atmospheric methane that is oxidised by methanotrophic bacteria.

The results of the calculations are shown in Table 93 and in Figure 48. As the table shows, emissions decreased from 1990 to 2003.

Table 93: N_2O, NO and NH_3 emissions E_{N2O}, E_{NO} and E_{NH3} from agricultural soils.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[Gg a^{-1} N_2O], [Gg a^{-1} NO] and [Gg a^{-1} NH_3]														
E_{N2O}	143	131	128	124	117	123	122	122	123	126	129	125	122	122	123
E_{NO}	64	58	56	54	51	54	53	53	54	56	57	55	53	53	53
E_{NH3}	115	105	99	103	93	104	104	106	109	117	121	125	124	123	128

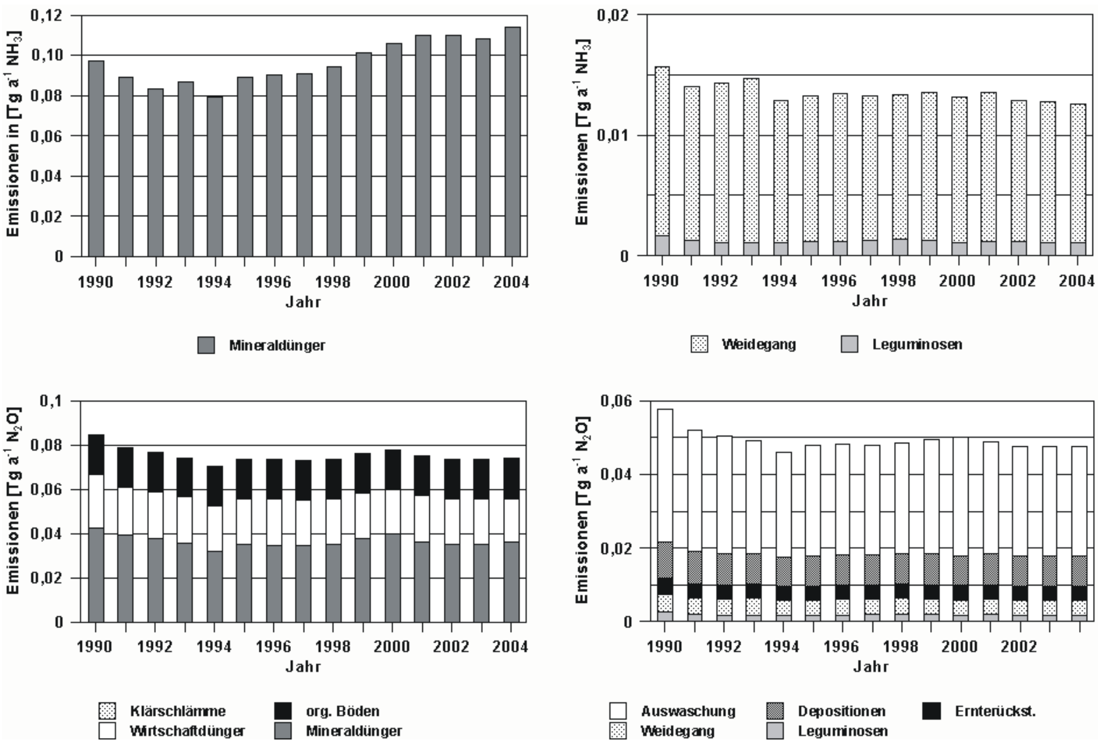


Figure 51: Time series for NH_3 and N_2O emissions from fertilised and unfertilised soils.[52]

For 2004, a share of about 30 % of N_2O emissions from soils can be allocated to use of mineral fertilisers in the soil; about 25 % can be allocated to indirect emissions resulting from leaching; and shares of about 15 % each can be allocated to spreading of farm manure and to cultivated organic soils. The remaining emissions consist of emissions from grazing, legumes, harvest residues and indirect emissions from deposition of reactive N species.

Use of mineral fertilisers also accounts for the largest share of NH_3 emissions: a share of 80 % in 1990 and of 89 % in 2004 (provisional value).

Table 94: NMVOC emissions E_{NMVOC} from agricultural plants.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[Gg a^{-1} NMVOC-C]														
E_{NMVOC}	0,086	0,110	0,108	0,108	0,108	0,109	0,098	0,105	0,113	0,125	0,120	0,124	0,135	0,130	0,135

[52] NH_3 emissions E_{NH3} from soils (above)
N_2O emissions E_{N2O} from soils (below).
In each case, N-fertilised systems on the left, while unfertilised systems are on the right.

Table 95: CH_4 consumption E_{CH4} by agricultural soils.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[Gg a^{-1} CH_4]														
E_{CH4}	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03	-0,03

6.4.2 Methodological issues und Anforderungen (4.D)

The IPCC (2000) describes Tier-1a and Tier-1b procedures for determining **direct nitrous-oxide emissions** from agricultural soils. The Tier-1a procedure is the procedure that conforms to IPCC (1996b). The Tier-1b procedure is more precise with regard to development of individual terms. Where sufficiently precise activity data is not available, calculation may be carried out in accordance with the Tier-1a method, however. In principle, both procedures use the following calculation steps:

1. Determination of N input from agricultural activities
2. Determination of emission factors for the various types of N input
3. Calculation of total emissions

The Tier-1a procedure differentiates between two different emission factors – one for emissions from N inputs and one for emissions from cultivation of organic soils (IPCC, 2000: S. 4-54):

Equation 9: Tier-1a procedure for determination of direct N_2O emissions from agricultural soils

$$E_{N_2O,\,direkt} = \left[\left(m_{SN} + m_{AM} + m_{BN} + m_{CR} + m_{SS}\right) \cdot EF_1 + \left(A_{OS} \cdot EF_2\right)\right]$$

where $E_{N2O,\,direct}$ — N_2O emissions [kg a^{-1} N]
- m_{SN} — N input via mineral fertilisers, adjusted for NH_3 and NO_X emissions [kg a^{-1} N]
- m_{AM} — N input via farm manure, adjusted for NH_3 and NO_X emissions [kg a^{-1} N]
- m_{BN} — N fixing by legumes [kg a^{-1} N]
- m_{CR} — N input via plant residues [kg a^{-1} N]
- m_{SS} — N input via sewage sludges [kg a^{-1} N]
- EF_1 — Emission factor for emissions from N inputs [EF_1 = 0.0125 kg kg^{-1} N]
- A_{OS} — Area of cultivated organic soils [ha]
- EF_2 — Emission factor for emissions from cultivation of organic soils [EF_2 = 8 kg ha^{-1} a^{-1} N]

N_2O emissions from animal excrement in connection with grazing should also be reported under direct emissions from soils; the relevant methods description and default EF are provided by IPCC (2000).

Indirect emissions are calculated via the following steps:

1. Determination of indirect N inputs via determination of N losses from agriculture due to emissions, surface run-off, leaching and wastewater management
2. Determination of emission factors for the various input types
3. Calculation of total emissions

The equation for determination of indirect N_2O emissions from agricultural soils is as follows:

Equation 10: Tier-1a procedure for determination of indirect N_2O emissions from agricultural soils

$$E_{\text{N2O,indirekt}} = E_{\text{N2O,ge}} + E_{\text{N2O,l}} + E_{\text{N2O,s}}$$

where
$E_{\text{N2O (indirect)}}$ indirect N_2O emissions [kg a^{-1} N_2O]
$E_{\text{N2O,ge}}$ N_2O emissions from emissions of NO_x and NH_3 from fertiliser, manure and liquid manure and their subsequent atmospheric deposition [kg a^{-1} N_2O]
$E_{\text{N2O,l}}$ N_2O emissions from surface run-off and leaching of spread fertilisers [kg a^{-1} N_2O]
$E_{\text{N2O,s}}$ N_2O emissions from wastewater discharge into surface waters [kg a^{-1} N_2O]
$E_{\text{N2O,ge}}$ N_2O emissions from emissions of NO_x and NH_3 from fertiliser, and their subsequent atmospheric deposition [Gg a^{-1} N_2O]
$m_{\text{N, fert}}$ Amount of mineral fertiliser applied [Gg a^{-1} N]
x_{fert} Fraction of mineral fertiliser that is emitted as NH_3 or NO_x [kg kg^{-1} N] (IPCC: $Frac_{\text{GASF}}$)
$m_{\text{N,ex}}$ Total amount of N in spread manure fertilisers [Gg a^{-1} N]
x_{ex} Share of manure fertiliser that is emitted as NH_3, NO, N_2O or N_2 [kg kg^{-1} N] (IPCC: $Frac_{\text{GASM}}$)
EF_4 Emission factor for N_2O emissions from atmospheric deposition [EF_4 = 0.010 kg kg^{-1} N]

Since Germany uses the mass-flow procedure to calculate N-species emissions, these emissions are inserted directly into calculations of indirect emissions. $Frac_{\text{GASF}}$ and $Frac_{\text{GASM}}$ are not constants.

No wastewater discharge into surface waters occurs (NO).

In most cases, the calculation methods comply with specifications for the simpler method described in the CORINAIR manual (EMEP, 2003). Specific details are provided in the relevant sections. The data on land under cultivation is taken from the official statistics for each reporting year. The emissions calculations for the years after 1999 are based on preliminary assumptions regarding land use.

6.4.2.1 Methane consumption of agricultural soils (4.D)

Calculation of CH_4 deposition is based on a proposal of BOECKX and VAN CLEEMPUT (2001), who summarise the available results of European measurements. The proposal calls for differentiation between grassland (EF_{CH4} = -2.5 kg ha^{-1} a^{-1} CH_4) and farmland (EF_{CH4} = -1.5 kg ha^{-1} a^{-1} CH_4). (in this regard, see the more detailed description in DÄMMGEN et al, 2006).

6.4.2.2 Emissions of non-methane volatile organic compounds from agricultural soils and crops (first estimate) (4.D)

Levels of NMVOC emissions from plants were estimated using the procedure set forth in the CORINAIR manual (EMEP, 2003). This source provides area-dependent emission factors for some of the main crops in question (for details, cf. DÄMMGEN et al., 2005).

6.4.2.3 Nitrous oxide and nitrogen monoxide emissions from agricultural soils (fertiliser use) (4.D)

For calculation, emissions of the two gases are assumed to be proportional, on the average, to N discharges into the system. N inputs from mineral fertilisers are taken from official statistics. Mineral fertiliser sales (for each German Land) serve as the activity data. The inputs from farm manure result from calculation of N flows in manure management (for details, cf. DÄMMGEN et al., 2006).

6.4.2.4 Nitrous oxide and nitrogen monoxide emissions from agricultural soils (legumes) (4.D)

The N quantities fixed via legumes are calculated from the areas under cultivation (DÄMMGEN et al., 2006) and from national averages for area-specific N fixing.

Equation 11: Determination of emissions of N species from legume cultivation

$$E_N = b \cdot EF_1 \cdot \sum_i A_i \cdot m_{NF,i}$$

where
- E_N Emission of N species [Gg a^{-1} N]
- b Conversion factor [10^6 kg Gg^{-1}]
- EF_1 Emission factor for emissions from N inputs [kg ha^{-1} N] (see below)
- A_i Cultivation area for a crop i [ha]
- $m_{NF,i}$ Fixed N amounts [kg ha^{-1} a^{-1} N] (see below)

Different fixed amounts $m_{NF,i}$ are differentiated, for:

Legumes	250 kg ha^{-1} N
Clover, clover/grass, clover/lucerne	200 kg ha^{-1} N
Lucerne	300 kg ha^{-1} N

The following emission factors are used:

$EF_{1,N2O}$	0.0125 kg kg^{-1} N
$EF_{1,NO}$	0.007 kg kg^{-1} N

Equation 12 is derived directly from Equation 4.21 in IPCC (2000). While that source proposes estimating $m_{NF,i}$, for different crop types, via yields or above-ground biomass, the above-described German procedure draws amounts of fixed N from tables. The activity is $\Sigma(A_i\ m_{NF,i})$.

6.4.2.5 Nitrous oxide and nitrogen monoxide emissions from agricultural soils (harvest residues) (4.D)

The N quantities remaining in the soil with harvest residues are calculated from the area under cultivation and the crop-specific N residues:

Equation 13: Determination of emissions of N species from harvest residues

$$E_{N2O_{Crop}} = EF_{N2O} \cdot m_{N_{Crop}} \cdot A_{Crop} \cdot \frac{44}{28} \cdot \beta$$

where
- $E_{N2O,Crop}$ N_2O emissions from cultivation of a crop [Gg a^{-1} N_2O]
- EF_{N2O} Emission factor [kg kg^{-1} N] (see below)
- $m_{N,Crop}$ Nitrogen amount in harvest residues [kg ha^{-1} a^{-1} N]
- A_{Crop} Area under cultivation with the relevant crop [ha]
- β Conversion factor [$\beta = 10^6$ kg Gg^{-1}]

The calculations use default emission factors for determination of emissions from use of mineral and farm fertilisers (IPCC et al., 1996b: Table 4-19 and EMEP, 2003: B1010-15): EF_{N2O} = 0.0125 kg kg^{-1} N; EF_{NO} = 0.007 kg kg^{-1} N; EF_{N2} = 0.1 kg kg^{-1} N. The same factors are also applied to the N amounts bound in harvest residues.

The following list indicates what N quantities are found in harvest residues (DÄMMGEN et al., 2005):

Wheat	17 kg ha^{-1} N
Rye	14 kg ha^{-1} N
Winter barley	12 kg ha^{-1} N

Summer barley	9 kg ha^{-1} N
Oats	14 kg ha^{-1} N
Triticale	12 kg ha^{-1} N
Grain corn	60 kg ha^{-1} N
Silo corn	26.7 kg ha^{-1} N
Rape	15 kg ha^{-1} N
Sugar beets	22 kg ha^{-1} N
Fodder beets	0.11 kg ha^{-1} N
Clover, clover/grass, clover/lucerne	40 kg ha^{-1} N
Lucerne	158 kg ha^{-1} N
Grass	30 kg ha^{-1} N
Potatoes	10 kg ha^{-1} N

The areas under cultivation are listed in LÜTTICH et al. (2005).

The CRF tables list emissions, but not the relevant activity rates or IEF. The relevant entries are "NA.

6.4.2.6 Nitrous oxide emissions from organic soils (4.D)

Nitrous oxide emissions from cultivation of *organic soils* are calculated in accordance with the simpler method. In this method, emissions are proportional to the area in question. Since no statistical data on use of such soils is available, the areas in question have been estimated via superpositioning of land-use maps and soil maps (for details, see DÄMMGEN et al., 2006). The emission factor used is the "new" default factor EF_2 (old: IPCC, 1996b: Table 4.18: 5 kg ha^{-1} a^{-1} N_2O-N; new: IPCC, 2000: Table 4.17: 8 kg ha^{-1} a^{-1} N_2O-N).

6.4.2.7 Nitrous oxide emissions from excrement produced during grazing (4.D)

In treatment of manure via the mass-flow procedure, emissions of N species that result from grazing on pastures are calculated for each species and district, using the relative quantities of excretions occurring on pastures, and then summed for all German Länder (for details, cf. DÄMMGEN et al., 2005).

The following emission factors are used (EMEP, 2003: B1010-13; IPCC, 1996b: Table 4-22):

NH_3	0.075 kg kg^{-1} N
N_2O	0.02 kg kg^{-1} N
NO	0.02 kg kg^{-1} N

6.4.2.8 Indirect nitrous oxide emissions resulting from atmospheric deposition (4.D)

N_2O emissions from atmospheric deposition are calculated using the following equation (Tier 1a):

Equation 14: Determination of indirect N_2O emissions from soils resulting from deposition of reactive N species from agriculture

$$E_{\text{N2O,ge}} = \left[\left(m_{\text{N,fert}} \cdot x_{\text{fert}}\right) + \left(m_{\text{N,ex}} \cdot x_{\text{ex}}\right)\right] \cdot EF_4 \cdot \frac{44}{28}$$

These indirect emissions comprise N_2O emissions from atmospheric deposition and from leaching and surface run-off. The pertinent NH_3 and NO emissions data is based on use of mineral fertilisers and on manure management. The data on use of mineral fertilisers and on legume cultivation comes from official statistics. NH_3 losses are calculated in accordance with EMEP (2003) and are not estimated in accordance with IPCC (1996b). IPCC default emission factors are used (IPCC Reference Manual, 1996b: Table 4-23).

6.4.2.9 Indirect nitrous oxide emissions resulting from leaching and surface run-off (4.D)

Under a simple Tier 1 procedure, N_2O emissions from leaching and surface run-off are considered to be proportional to N inputs into the soil. The CRF calls for fugitive nitrogen releases from mineral fertilisers and farm manure to be listed as a source. IPCC default values are used for the leachable fraction and for the emission factor (IPCC Reference Manual, 1996b: Tab. 4-24 and Tab. 4-23).

The N_2O emissions are calculated pursuant to the following formula:

Equation 15: Determination of indirect N_2O emissions from soils resulting from leaching of nitrogen from agriculture soils

$$E_{\mathrm{N2O,l}} = \left(m_{\mathrm{man}} + m_{\mathrm{fert}} + m_{\mathrm{SS}}\right) \cdot x_{\mathrm{leach}} \cdot EF_5 \cdot \frac{44}{28}$$

where:
- $E_{\mathrm{N2O,l}}$ N_2O emissions from leaching and surface run-off [Gg a^{-1} N_2O]
- m_{man} N input via manure [Gg a^{-1} N]
- m_{fert} N input via manure fertilisers [Gg a^{-1} N]
- m_{SS} N input via sewage sludge [Gg a^{-1} N]
- x_{leach} Leachable N fraction [kg kg^{-1} N]
- EF_5 Emission factor for N_2O emissions from leaching [EF_5 = 0.025 kg kg^{-1} N]

6.4.3 Uncertainties and time-series consistency (4.D)

The uncertainties are outlined in EMEP/CORINAIR (EMEP, 2003); they apply to Germany as well until further notice. The detailed discussion in this source indicates that the error for relevant areas is on the order of 10 % and that the error for emissions is on the order of 50 %. The time series is consistent.

6.4.4 Source-specific quality assurance / control and verification (4.D)

The data is reviewed for transcription errors made between the original data and the calculation tables, and it is checked for errors with regard to units and orders of magnitude. Future QA/QC procedures pre-suppose the further development of methods and a better breakdown of activity data (cf. Chapter 6.1.4).

At present, Germany does not have any numerical basis for better description of data quality and uncertainties.

6.4.5 Source-specific recalculations (4.D)

6.4.5.1 Methane consumption of agricultural soils (4.D)

No source-specific recalculations have been carried out.

6.4.5.2 Nitrous oxide and nitrogen monoxide emissions from agricultural soils (4.D)

For the first time, sewage sludges and imported manure fertilisers were included. This changes the figures for direct emissions from soils.

Use of detailed methods to calculate of N excretions in animal husbandry, inclusion of goat and buffalo populations and inclusion of sewage sludges led to changes in relevant direct emissions of NH_3 and NO. The indirect emissions also have changed as a result.

Table 96: Comparison of figures used in the NIR 2005 and NIR 2006 for direct N_2O emissions from agricultural soils.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[Gg a^{-1} N_2O]														
NIR 2005	97,3	90,1	87,4	85,0	80,6	84,3	84,2	83,8	84,5	86,3	87,8	84,9	83,1	82,6	
NIR 2006	97,1	89,7	87,2	84,9	80,5	84,2	84,1	83,6	84,4	86,7	88,3	86,0	84,2	84,2	84,5

Table 97: Comparison of figures used in the NIR 2005 and NIR 2006 for indirect N_2O emissions from agricultural soils.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[Gg a^{-1} N_2O]														
NIR 2005	44,2	40,2	38,9	37,5	35,2	37,0	36,9	36,5	36,9	37,9	38,7	37,2	36,2	36,0	
NIR 2006	45,9	41,6	40,3	38,9	36,7	38,6	38,4	38,0	38,4	39,7	40,6	39,1	38,2	38,1	38,1

Table 98: Comparison of figures used in the NIR 2005 and NIR 2006 for NO emissions from agricultural soils.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[Gg a^{-1} NO]														
NIR 2005	65,6	59,6	57,5	55,6	52,0	54,8	54,9	54,5	55,0	56,3	57,4	55,3	53,7	53,2	
NIR 2006	63,9	57,9	56,1	54,4	50,7	53,5	53,5	53,1	53,7	55,5	56,7	54,6	53,2	53,1	53,2

Table 99: Comparison of figures used in the NIR 2005 and NIR 2006 for NH_3 emissions from agricultural soils.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[Tg a^{-1} NH_3]														
NIR 2005	0,122	0,111	0,105	0,109	0,099	0,110	0,111	0,112	0,115	0,122	0,126	0,131	0,129	0,127	
NIR 2006	0,115	0,105	0,099	0,103	0,093	0,104	0,104	0,106	0,109	0,117	0,121	0,125	0,124	0,123	0,128

6.4.6 Planned improvements (source-specific) (4.D)

6.4.6.1 Ammonia emissions from agricultural soils (4.D)

These emissions are to be further disaggregated, both spatially and chronologically; to this end, applied amounts of fertiliser are to be differentiated by grassland and cropland. The amounts spread in individual rural districts are to be plausibly estimated. Chronological resolution of 1 month is planned.

Emissions during grazing are also to be determined within a chronological resolution of 1 month.

6.4.6.2 Nitrous oxide and nitrogen monoxide emissions from agricultural soils (4.D)

Medium-term plans call for use of a Tier-3 method for calculation of emissions of these gases. In the short term, an attempt will be made to evaluate the literature with regard to NO emissions from agricultural lands, in order to obtain better emission factors.

6.4.6.3 Uncertainty relative to emissions from agricultural soils (4.D)

In future, the statistics on which emissions calculation is based will have to be expanded to include error and scattering, to make it possible to calculate the required uncertainties. The current inventory of agricultural emissions already responds to this need. The total error arising from the individual errors in the terms of a complex emission function should be determined by means of an error-propagation calculation. Here, this should be carried out especially for NH_3 emissions leading to indirect emissions, as well as for the N amounts added to the soil following application of farm manure.

6.5 Prescribed burning of savannas (clearance of land by prescribed burning (4.E)

Land clearance by prescribed burning is not practiced in Germany (NO).

6.6 Field burning of agricultural residues (4.F)

Burning of agricultural residues is prohibited in Germany. It is not possible to collect data on permitted exceptions. Such exemptions are considered to be irrelevant (NO).

6.7 Other areas (4.G.)

6.7.1 Source-category description (4.G)

The source category "Other areas" currently comprises particulate emissions from animal husbandry in stables and from land cultivation. This area is being reported on for the first time.

Table 100: PM10 emissions E_{PM10} from tilling of cropland.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[Gg a^{-1} PM10]														
E_{PM10}	0,086	0,110	0,108	0,108	0,108	0,109	0,098	0,105	0,113	0,125	0,120	0,124	0,135	0,130	0,135

Table 101: PM_{10} and $PM_{2.5}$ emissions E_{PM10} and $E_{PM2.5}$ from animal husbandry.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	[Gg a^{-1} PM]														
E_{PM10}	35,3	32,3	31,7	31,4	33,4	33,0	33,8	33,8	34,3	35,4	35,1	35,8	35,8	36,8	36,4
$E_{PM2.5}$	7,9	7,1	6,8	6,7	6,9	6,9	6,9	6,9	6,9	7,0	6,9	7,0	6,9	7,0	6,9

6.7.2 Methodological issues and requirements (4.G)

Guidelines for describing dust emissions were lacking at the time of inventory preparation. For this reason, dust emissions from cropland tilling were determined by means of a procedure described by KLIMONT et al. (2002) and used by IIASA. This procedure relates the emissions to pertinent tilled areas:

$$E_{PM10} = \sum A_a \cdot EF_{PM10} \cdot ß$$

where E_{PM10} Emissions [Gg a^{-1} PM_{10}]
A_a Cropland area [ha]
EF_{PM10} Emission factor [EF_{PM10} = 0.1 kg ha^{-1} a^{-1} PM_{10}]
β Mass-conversion factor [$\beta = 10^{-6}$ Gg kg^{-1}]

The required land-area figures are taken from land-use statistics.

Calculation of emissions from animal husbandry is confined to emissions from stables. In this area, a draft guideline with the status of a first estimate is available (EMEP, 2005).

$$E_{PM,i} = x_{house,i} \cdot \beta \cdot (x_{slurry,i} \cdot EF_{slurry,i} + x_{solid,i} \cdot EF_{solid,i})$$

where

$E_{PM,i}$	PM emissions of animal category i [Gg a^{-1} PM]
β	Mass-conversion factor [$\beta = 10^{-6}$ Gg kg^{-1}]
x_{house}	Time share spent in stable [a a^{-1}]
x_{slurry}	Population share in liquid-manure systems
EF_{slurry}	Emission factor for liquid-manure systems [kg $place^{-1}$ a^{-1}]
x_{solid}	Population share in solid-manure systems
EF_{solid}	Emission factor for solid-manure systems [kg $place^{-1}$ a^{-1}]

The animal head counts are taken from statistics. They are corrected as necessary. This procedure is available for only some animals. For example, relevant figures for poultry are largely lacking. The pertinent emission factors are shown in the following table:

Table 102: PM emission factors EF_{PM} for animal husbandry

Animal category	Stall type	Emission factor for PM_{10} [kg $place^{-1}$ a^{-1}]	Emission factor for $PM_{2.5}$ [kg $place^{-1}$ a^{-1}]
Dairy cows	Tethered or in stalls with straw	0,36	0,23
	Box stalls with walking room (liquid manure / slurry)	0,70	0,45
Heifers and fattening bulls	Solid manure	0,24	0,16
	Liquid manure / slurry	0,32	0,21
Calves	Solid manure	0,16	0,10
	Liquid manure / slurry	0,15	0,10
Sows	Solid manure	0,58	0,094
	Liquid manure / slurry	0,45	0,073
Piglets	Solid manure	*	*
	Liquid manure / slurry	0,18	0,029
Fattening swine	Solid manure	0,50	0,081
	Liquid manure / slurry	0,42	0,069
Horses	Solid manure	0,18	0,12
Laying hens	Cage	0,017	0,0021
	Flight cage	0,27	0,052
Fattening cocks and hens	Solid manure	0,35	0,045

* no emission factor given

6.7.3 Source-specific recalculations (4.G)

The calculations were carried out for the first time. Therefore, no source-specific recalculations are required.

6.7.4 Uncertainties and time-series consistency (4.G)

The database for the emission factors is relatively small. The figures are likely to be of the correct order of magnitude. The time series are consistent.

6.7.5 Source-specific quality assurance / control and verification (4.G)

Quality assurance was not possible.

6.7.6 Planned improvements (source-specific) (4.G)

The emission factors for the circumstances prevailing in Germany are to be improved via a research project.

7 LAND USE, LAND-USE CHANGES AND FORESTRY (5)

CRF 5					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990- contribution to total emissions**	**2004- contribution to total emissions**	**Trend**
Forest Land (5.A)	l / t	CO_2	5,53 %	6,92 %	rising
Cropland (5.B)	l / t	CO_2	2,09 %	2,38 %	rising
Grassland (5.C)	l / t	CO_2	1,46 %	1,58 %	rising

In light of their emissions levels and trend, the source categories “Forests” (5.A), “Cropland” (5.B) and “Grassland” (5.C) are key CO_2 emission sources.

7.1 Forests (5.A)

The basis for reporting consists of the definition of "forest" used by the Federal Forest Inventory (Bundeswaldinventur - BWI)[53]. The BWI's survey instructions differentiate between the following sub-categories of forest:

- Productive forest, wooded ground[54]
- Unproductive forest[55], wooded ground[53]
- Forest, openings[56]
- Forest, non-wooded ground[57]

In calculations for greenhouse-gas inventories, the categories "unproductive forest" and openings were included with forest, while non-wooded ground, in keeping with the definition of "forest" used in decision 11/CP.7 of the 7th Conference of the Parties in Marrakesh (UNFCCC, 2002: p. 58) was excluded, as non-forest.

In the Good Practice Guidance for Land use, Land-use Change and Forestry (GPG-LULUCF, IPCC, 2003), in the official reporting tables for the greenhouse-gas inventories sent to the Climate Secretariat and in the "Common Reporting Format" (CRF), the category "forest" 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 created, via afforestation or natural succession, on areas previously used for other purposes). Pursuant to IPCC GPG-LULUCF (2003), new forest remains for at least 20 years within this category, after which it is transferred to the "remaining forest land" category.

[53] Forest within the meaning of the FFI is any area of ground covered by forest vegetation, irrespective of the information in the 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, landings, rides located in the forest, 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. Areas with forest cover in open pasture land or in built-up areas of under 1000 m², coppices under 10 m wide and the cultivation of Christmas trees and ornamental brushwood as well as parkland attached to country houses are not forest within the meaning of the FFI. Watercourses up to 5 m wide do not break the continuity of a forest area. The cultivation of Christmas trees and ornamental brushwood in the forest is forest within the meaning of the Federal Forest Inventory (BMELF, 1990).

[54] The wooded-ground area is that part of the forest that is covered with trees used in forestry and that is used for wood production.

[55] Unproductive forest areas are fields of dwarf pines and green alders, areas of shrubs (but not openings) and other forest areas which are sparsely covered or which have low productivity (≤1 m³ average total growth (dGZ)/hectare).

[56] Openings are areas of wooded ground temporarily without forest cover.

[57] Non-wooded ground includes forest tracks, rides and firebreaks over 5 m wide, landings, tree nurseries, seed and plant nurseries, wood-pastures and fields for game, the areas of yards and buildings used for forestry purposes, recreational facilities linked to the forest and rocks, boulders, gravel and water located in the forest. In addition, if they are not overgrown, swamps and moors located in the forest come under non-wooded ground.

In Germany, with existing data, new forest additions in the old German Länder can be traced only back to 1987; for the new German Länder, it has been possible only to derive the net new forest since 1993.

7.1.1 Forest Land remaining Forest Land (5.A.1)

7.1.1.1 Source-category description (5.A.1)

Gas	CO_2	CH_4	HFC	PFC	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)	CS									
EF uncertainties in %										
Distribution of uncertainties										
Method of EF determination	CS/T2 [58]									

The source category "forest land remaining forest land" has not yet been subjected to key-source analysis.

7.1.1.1.1 Changes in biomass

For the old German Länder, data is available from two federal forest inventories (key dates: 1 October 1987 and 1 October 2002) (BFH, 2004). Between the two forest inventories, C stocks in forests of the old German Länder underwent a net increase of 1.52 Mg/ha/a. The increase in stocks is a result of low use, in comparison to growth. For the new German Länder, data from the Federal Forest Inventory II (BWI II) was compared with forest-establishment data, given the lack of an initial inventory comparable to BWI I. The comparison showed a marked net C-stock increase of 3.01 Mg/ha/a.

It seems clear that the forest-establishment data underestimates stocks. If the initial value for total stocks is assumed to be 10 % higher (and evenly distributed among all tree species), a marked net C-stock increase of 2.32 Mg/ha/a results.

Overall, the forests of the Federal Republic of Germany are thus a net sink for C.

7.1.1.1.2 Dead wood, debris and soils

For greenhouse-gas inventories, it was assumed that stocks under existing forest do not change (corresponds to "Tier 1").

7.1.1.1.3 Other greenhouse-gas emissions from forests

Figures for CO_2 emissions from liming of forest soils are provided in category 5.G. (Other). They range between 130 and 210 Gg CO_2 per year, and are tending to decrease.

Forests in Germany are not normally given nitrogen fertilisers. In CRF Table 5(I), therefore, this activity has been marked "NO". No reliable data is available for reporting on N_2O emissions from draining of forest soils (CRF 5(II)).

BUTTERBACH-BAHL (2003), using the PnET-N-DNDC model, estimated total nitrous oxide (N_2O) emissions from forest soils for the years 1990-1999 as amounting to about 14 Gg per year. This figure includes "indirect" N_2O emissions, however, which originate in sources outside of the forestry sector and thus are outside the scope of greenhouse-gas inventories for forest soils.

58 Die Angabe CS/T2 bezieht sich auf die Ermittlung der Vorratsänderung in der Biomasse. Änderungen in Totholz, Streu und Boden wurden nach Tier 1 auf 0 geschätzt.

As a result of use of the "stock-change method", CO_2 from biomass combustion has already been taken into account in changes of biomass stocks; the entry for this category is thus "IE".

Emissions of other greenhouse gases from forest fires and from controlled biomass combustion have been classified as negligible and, in Table 5 (V) "Biomass burning", reported as "NO", since only small areas of Germany are affected by forest fires and since logging areas are burned only in exceptional cases – for example, in cases of bark-beetle infestation. Burning-off of vegetated areas is prohibited in Germany.

7.1.1.2 Methodological issues (5.A.1)

7.1.1.2.1 Data sources

The basis for the biomass and area calculations consists of the data from the two Federal Forest Inventories. Pursuant to provisions of the GPG-LULUCF (IPCC 2003), this data is processed in keeping with requirements pertaining to international reporting obligations.

The Federal Forest Inventory (Bundeswaldinventur – BWI) is a terrestrial random-sampling inventory with permanently marked sampling points in a 4 x 4 km basic grid whose resolution, at the request of the Länder, can be increased on a regional basis[59].

The first Federal Forest Inventory, BWI I, covered only the territory of the Federal Republic of Germany in its pre-1990 boundaries and West berlin. For the new German Länder, therefore, forest-establishment data has to be taken from another source – the publication "The Forest in the New German Länder" ("Der Wald in den neuen Bundesländern" (BML, 1994)).

Due to the differences in the data situations for the two areas, and to the resulting need to use different calculation methods, reporting in the CRF tables is broken down by old and new German Länder.

Now, with the Federal Forest Inventory II (BWI II) and Soil-Condition Survey (Bodenzustandserhebung - BZE), first inventories are available for the categories of deadwood, debris and soils. While this makes it possible to estimate the C stocks in these categories, it does not made it possible to determine the relevant changes.

The deadwood stocks of 11.5 m^3/ha found by the BWI II correspond to C stocks of some 2.6 Mg C /ha.

Finer debris fractions are part of the humus layer, which was surveyed by the BZE. The first BZE, which was carried out from 1987 to 1993, estimated the carbon stocks in the humus layer, and in the first 30 cm of mineral soil lying beneath the humus layer, as amounting to about 0.858 Pg C (BMELF, 1997).

Data on liming of forest soils was derived from fertiliser statistics (Düngemittelstatistik) published by the Federal Statistical Office (DESTATIS, Fachserie (technical series) 4, Reihe 8.2) and from statistics of the former GDR. From 1993/94 onwards, the results have been collected and published for unified Germany.

Data on areas on which forest fires have occurred, since 1992, is available in official forest-fire statistics pursuant to Council Regulation (EEC) No. 2158/92 of 23 July 1992 on protection of the Community's forests against fire; excerpts from the forest-fire statistics are published in BML 1992ff..

[59] Further information: http://www.bundeswaldinventur.de and http://www.bundeswaldinventur.de/Verdichtung.gif

7.1.1.2.2 Forest land remaining as forest land

Forest-area data is not required for calculation of biomass stocks pursuant to the stock-change method, but it must be reported in the CRF. The area data for individual years is based on linear interpolation.

Pursuant to the results of the two Federal Forest Inventories, in the old German Länder, the total forest area (not including the non-timber area) increased by 54.12 kha, to 7,693.72 kha, between 1987 and 2002. Pursuant to IPCC GPG-LULUCF (2003), new forest must be classified as "new forest" for a period of 20 years, and thus each year the category "forest land remaining forest land" is reduced by that forest area converted to other land uses. The category "forest land remaining forest land" thus decreased from 7,626.14 kha (1990) to 7,572.27 kha (2002).

According to forest-establishment data, in the new German Länder, the forest area (not including non-wooded ground) in 1993 amounted to 2,852.5 kha; by BWI II it had increased to 3,027 kha. As a result, the first of these values can assigned to the category "forest land remaining forest land".

7.1.1.2.3 Derivation of stock changes pursuant to the "stock-change method" (difference method)

The Federal Forest Inventories provided such good data for calculation – measuring about 230,000 trees in key year 1987 (BWI I) and some 377,000 trees in key year 2002 (BWI II) – that it was possible to use the "stock-change method" instead of the "default method" (incremental extrapolation, as carried out for previous inventories) (IPCC, 2003: p. 3.24).

For use of the stock-change method, the relevant living biomass was divided into the following categories: standing-timber volume, branch wood volume and root mass. Above-ground volumes were converted into masses using specific volume densities for the various tree species in question. The basic equation (Equations 16 and 17) for C-stock determination via the stock-change method was thus converted into a form pursuant to Equation 18. The first part of Equation 18 (standing timber, branch wood) was applied to each tree, while the second part was applied to stands. The total value was then extrapolated from the stand values.

Equation 16

$$\Delta C = \left(C_{t_2} - C_{t_1}\right) / \left(t_2 - t_1\right)$$

Equation 17

$$C = \left[V \bullet D \bullet BEF\right] \bullet \left(1 + R\right) \bullet CF$$

Equation 18

$$C = \underbrace{[V \bullet D_D}_{\text{Standing timber}} + \underbrace{V \bullet D_A \bullet (VEF-1)]}_{\text{Branch wood}} \bullet \underbrace{(1+R)}_{\text{Root wood}} \bullet CF$$

where:
C = Carbon stocks
V = Volume of standing timber
D_D = Volume density of standing timber
D_A = Volume density of branches
BEF = Biomass-expansion factor
VEF = Volume-expansion factor[60]
R = Root / shoot ratio
CF = Carbon fraction

7.1.1.2.4 Procedure

For central European conditions, there are no generally valid biomass functions that could have been applied to the inventory's measured data (a function for spruce is one exception).

For this reason, a procedure was applied whereby the standing-timber volume, as determined in the inventory, is converted into the above-ground tree volume. The above-ground tree volume includes branches and, for evergreen trees, the leaf organs. Volume-expansion factors were used to estimate the tree-wood volume from the standing-timber volume (cf. Chapter 7.1.1.2.7).

For the new German Länder, forest-establishment data is available in aggregated form. For this reason, the C-balancing method pursuant to BURSCHEL et al. (1993), in conjunction with volume densities pursuant to KOLLMANN (1982), was used for C-stock determination.

7.1.1.2.5 Total stocks of remaining forest land

The results described here refer, in connection with individual-tree calculations for BWI I and BWI II, to volume densities pursuant to KOLLMANN (1982), whereas branch volumes, with their greater densities, were extrapolated pursuant to HAKKILA (1972). Regression equations were used to estimate above-ground tree volumes (cf. Annex). Root biomass was calculated using default values from IPCC GPG-LULUCF (2003). In the extrapolation for the new German Länder for 1993, the biomass-expansion factors of BURSCHEL et al. (1993) were separated into above-ground and below-ground components, and the above branch volume was estimated from the difference between above-ground volume and standing-timber volume. In the interest of comparability between the extrapolation of forest-establishment data and individual-tree calculation pursuant to BWI, the same volume densities were used throughout this process.

[60] The biomass-expansion factor (BEF) is used here in keeping with IPCC. In the literature, the term "BEF" is used in a variety of very different ways. For this reason, in the following, the term "volume-expansion factors" (VEF) is used, which describes the relationship above-ground volume / standing-timber volume.

Table103: Total C stocks, forest land remaining as forest land, with estimate of the relative standard error

Gg C		**1987 (BWI I)**	**1993 (BML)**	**2002 (BWI II)**
Old German Länder	Below ground	174,670	-	212,849
	Above ground	604,474	-	740,481
	Total	**779,144 (± 8%)**	**-**	**953,330 (± 7.55%)**
New German Länder	Below ground.	-	34,723	63,690
	Above ground.	-	161,766	218,667
	Total	**-**	**196,489 (±12.71 %)**	**282,357 (± 10.02 %)**

7.1.1.2.6 Volume density of trunk wood and branches

The volume densities were derived from the figures provided by KOLLMANN (1982) for raw density and volume-loss measures (cf. Annex), using Equation 19:

Equation 16

$$R = r_0 * \left(1 - \frac{\beta_V}{100}\right)$$

where:
R= Volume density (g/cm^3)
r_0= Raw density (g/cm^3)
$ß_V$= Volume-loss measure

Pursuant to Equation 18, other volume densities are used for branches. Due to the stresses it is subject to, branch wood is denser than trunk wood. Separation into various categories makes it possible to use different densities. The relevant necessary data was derived by analogy to HAKKILA (1972).

Furthermore, figures for volume density of trunk wood vary widely. For this reason, calculations were carried out for a range of different scenarios (cf. Annex 14.5.1.1.1.2.7).

7.1.1.2.7 Volume-expansion factors

The volume-expansion factors (VEF) for conversion of standing timber into above-ground biomass were derived from a linear regression and are based on the tables of GRUNDNER & SCHWAPPACH (1952) for standing timber and tree wood. These factors provide a functional relationship between standing timber and tree wood. This makes it possible to estimate tree-wood amounts from the size of standing timber, which itself depends on the measurements diameter at a height of 1.3 m, diameter at a height of 7 m (BHD, D_7) and height. In addition, the tables call for separation, by age classes, for the tree species spruce, fir, beech and pine, since for these trees it was found that, for trunks with the same dimensions, older trunks have a greater volume than younger trunks; the older trunks have a greater wood fraction (Table 149). This separation was retained, since the tables are based on separate basic totalities.

The following relationship thus results for the various volume-expansion factors for specific species and tree ages:

Equation 17

$$VEF = \frac{B}{D} = \frac{a + bD}{D}$$

where:
B = Tree-wood volume
D = Standing-timber volume
a, b = Regression parameters
VEF = Volume-expansion factor

7.1.1.2.8 Root biomass

Dry-root substance was estimated directly from above-ground mass, at the stand level, using the root/shoot ratio with values pursuant to IPCC 2003. To obtain stand values, the above-ground biomass, differentiated by tree-species groups, was extrapolated to the hectare level for each sampling point, and then the below-ground biomass was derived.

A comparative calculation, in keeping with the function published DIETER & ELSASSER (2002) for estimating root biomass, produced similar results (Annex, Chapter 14.5.1.1.1.2.10).

7.1.1.2.9 Derivation of CO_2 emissions from liming of forest soils

The liming data was derived from the total fertilisers calculation. It describes producers' and importers' deliveries to wholesalers and end users (DESTATIS, Fachserie (technical series) 4, Reihe 8.2). For the calculation, the amount of fertiliser spread was assumed to be the same as the amount sold. The relevant emissions were derived using equation 3.3.6 from IPCC GPG-LULUCF (2003: p. 3.80).

7.1.1.3 Uncertainties and time-series consistency (5.A.1)

The uncertainties were calculated for aggregated stocks, for the two Federal Forest Inventories and broken down by old and new German Länder.

For the old German Länder, stratification was carried out in accordance with tree-species groups pursuant to BWI (ALH[61], ALN[62], beech, douglas fir, oak, spruce, pine, larch, fir). To this end, the relative standard error is estimated or calculated for each input item (standing-timber volume, volume density, above-ground biomass expansion, root biomass and carbon fraction). This relative standard error is then extrapolated using the extrapolation procedure in question – additive error propagation or multiplicative error propagation. The calculation does not take account of every possible error source (divergence of allometry, model errors in standing-timber calculation, measurement errors). Errors are derived using practical approaches, and thus such derivation provides only an approximation of the actual errors at work. Correlations between individual terms were neglected.

As a result, one obtains an estimate of the relative standard error of the total stocks. The 95% confidence interval for this estimate corresponds to double the relative standard error.

For the new German Länder, errors for C stocks can be calculated only as estimates, based on aggregated values; this is accomplished pursuant to the publication "The forest in the new German Länder" ("Der Wald in den neuen Bundesländern" (BML 1994)).

[61] ALH = all other deciduous trees with high life expectancies
[62] ALN = all other deciduous trees with low life expectancies

Error propagation for the periods 1993 (BML, 1994: new German Länder), 1987 (BWI I: old German Länder) and 2002 (BWI II: new and old German Länder) is presented in the Annex (Table 158), while the relative standard error has been added as an overview inTable 103.

The greenhouse-gas inventory for 2005 presents newly calculated data for all years since 1990. Time-series consistency is thus assured. At the same time, reporting has been converted in keeping with the new CRF tables adopted at the 9th Conference of the Parties in Milan.

7.1.1.4 Source-specific quality assurance / control and verification (5.A.1)

The carbon-stocks estimates for the various periods are based on ACCESS queries of the data from the Federal forest inventories; with regard to the quality assurance developed for the Federal Forest Inventory, the reader's attention is called to the literature for the Federal Forest Inventory.

First, an estimate was carried out using the BURSCHEL et. al. (1993) method, to provide an indication of the orders of magnitude of the carbon-stock extrapolation. This estimate, which is based on aggregated values (average stocks, by tree-species groups), was carried out by two different persons, using two different methods (published BWI results and ACCESS queries). The results obtained with the two methods agreed.

In the individual-tree calculations, a "Burschel" scenario (cf. Annex Chapter 14.5.1.1.1.2.5) , using the same volume densities used for the estimate (using aggregated values), was calculated. The resulting values agreed with the calculations using the aggregated values. Consequently, it is clear that the ACCESS queries, in general, provide correct values; on the other hand, their results can deviate depending on what assumptions are made for volume densities and root-shoot ratios.

One systematic error persists, however: It was not possible to estimate rejuvenation below the standing-timber threshold, and the relevant figure is not found in the stock data, because the volume-expansion function is based on standing-timber volumes. The lack of rejuvenation stocks results in a systematic underestimation of total stocks.

7.1.1.5 Source-specific recalculations (5.A.1)

Pursuant to the above-described recalculation, stock increases are twice as high as listed in previous inventories. The main reason for this is the wood-stock increase determined in BWI II, an increase that far exceeds existing yield-table estimates. Other factors include inclusion, for the first time, of underground biomass, improved methods of calculation and underestimation of the outset stocks in the new German Länder (BML, 1994).

7.1.1.6 Planned improvements (source-specific) (5.A.1)

No improvements are planned.

7.1.2 Land converted to Forest Land (5.A.2)

7.1.2.1 Source-category description (5.A.2)

Forest is created through succession, afforestation and reforestation; new forest areas begin storing C equivalents as soon as they are converted. In a rigorous approach, the C-stocks of previous land uses should be deducted. But no data is available on previous plant coverage (for example, individual trees, hedges or long-lived woody cultivations) and its biomass.

Overall, such stocks are considered negligible, especially since the total area of new forest land is very small in comparison to the total forest area (old German Länder 2002: 121 kha to 7,694 kha).

7.1.2.2 Methodological issues (5.A.2)

7.1.2.2.1 New forest land

Pursuant to IPCC GPG-LULUCF (2003), new forest lands must remain in the category "new forest lands" for 20 years. No land-use-change data that could support comparisons is available prior to BWI I.

For the old German Länder, direct comparison between BWI I and BWI II makes it possible to separate new forest land and deforested land since 1987. The new forest lands occurring between BWI I (key year 1987) and BWI II (key year 2002), and amounting to 121.45 kha (not including the non-wooded ground) can be categorised as follows in keeping with their existing uses:

Table 104: New forest lands, old German Länder

Outset category	Area [kha]	Annual increase in area [kha/a]
Cropland and long-lived cultivations	30,57	2,04
Permanent grassland	45,46	3,03
Wetlands	15,67	1,04
Settled areas	29,75	1,98

To derive area data for individual years, a linear increase in the new forest lands in BWI I and II was assumed and included in the CRF tables. In comparison to the total forest area of the old German Länder in 2002, 7693.72 kha, these additional areas, totalling 1.58% in 15 years (both figures without non-wooded ground) are marginal.

For the new German Länder, only the net forest-land increase between 1993 and 2002 can be determined; it amounts to 174.56 kha. This difference is considered the new forest land. Its annual rate of increase is 17.46 kha/a; the data does not permit any allocation into outset categories. The area increases were assumed to progress linearly between 1993 and 2002.

7.1.2.2.2 Biomass stocks, new forest land

For the old German Länder, it was possible to carry out an individual-tree calculation for new forest land. First, the stocks were calculated for the entire new forest land. Then, the stocks were distributed throughout the entire new forest area and divided among the sub-categories in accordance with the relevant area shares (Table 105).

Table 105: Stocks, new forest lands, end of 2002

Outset category	Stocks [Gg C]
Cropland and long-lived cultivations	922
Permanent grassland	1.372
Wetlands	473
Settled areas	897

Since for the new German Länder wood stocks on new forest lands cannot be derived directly from comparison of two inventories, hectare values were derived from the standing-timber stocks of tree-species groups in the 1^{st} age class (0-20 years, BWI II new German Länder) and converted into C stocks. In light of the young age of of the new forests that have developed since 1993, this value was then cut in half. This produces a value of 18.01 Mg/ha, or total stocks of 3,144 Gg C, for these areas at the end of the 2002 vegetation period.

The biomass stocks at the end of the 2002 vegetation period correspond to the biomass stock increases throughout the entire period under consideration since 1987 (old German Länder) and 1993 (new German Länder), as long as any possible previous plant cover is ignored. These stock increases were weighted with the new forest area produced in the relevant report years, and then they were linearly interpolated throughout the entire period under consideration.

7.1.2.2.3 Stocks in dead wood, debris and soils on new forest areas

Since in our latitudes it takes decades for typical forest stocks to develop in these categories, the annual increase was considered negligible and not taken into account in the greenhouse-gas inventory.

7.1.2.3 Uncertainties and time-series consistency (5.A.2)

Possibilities for estimating uncertainties more precisely and for improving time series consistency will be considered in 2006.

7.1.2.4 Source-specific quality assurance / control and verification (5.A.2)

7.1.2.5 Source-specific recalculations (5.A.2)

7.1.2.6 Planned improvements (source-specific) (5.A.2)

No improvement measures are planned.

7.2 Cropland (5.B)

The emissions estimate for 2004 is based on extrapolation of the results from previous years.

According to this estimate, the total CO_2 emissions from cultivation of cropland amounted to 25,007 Gg CO_2. Of this figure, 20,264 Gg CO_2 were releases from cultivated bogland. A total of 3,226 Gg CO_2 was released from mineral soils, as a result of usage changes on cropland or of conversion from perennial crops to annual crops or vice-versa. As a result of such land use and land-use changes, a total of 36 Gg CO_2 was stored in above-ground biomass.

Release of N_2O as a result of conversion of grassland, fallow land, permanent cultivations and forest land to cropland was calculated at 1.36 Gg N_2O, corresponding to 421.6 Gg CO_2 equivalents.

An additional 1,554 Gg CO_2 was released as a result of liming. While this total refers non-specifically to all agricultural lands, it was assigned wholly to cropland cultivation.

7.2.1 Source-category description (5.B)

	- / -				

Gas	CO_2	CH_4	HFCs	PFCs	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)	CS/D									
EF uncertainties in %										
Distribution of uncertainties										
Method of EF determination	CS/T2[26]									

The source category "Cropland" has not yet been subjected to key-source analysis.

Pursuant to IPCC GPG LULUCF (2003), carbon-stock changes in soil and biomass stocks are reported under the category "cropland". The land area subsumed under "cropland" consists of:

1. Cropland with annual crops

- Wheat, rye, summer and winter barley, oats, triticale, fodder plants, silo corn, potatoes, sugar beets, non-food crops – especially winter rape (broken down by crop only for biomass determination)

2. Cropland with perennial crops

- Fruit crops, osiers, poplars, Christmas tree farms, nurseries (long-lived crops)
- Vineyards

Reporting under "cropland" is based on definitions for the usage-type key of the Working group of surveying administrations of the Länder of the Federal Republic of Germany (Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder der Bundesrepublik Deutschland - AdV), in the "Directory of area-based usages in the property cadastre and their definitions" ("Verzeichnis der flächenbezogenen Nutzungsarten im Liegenschaftskataster und ihrer Begriffsbestimmungen" - AdV, 1991), and on the "Ground-cover nomenclature" ("Nomenklatur der Bodenbedeckungen") of the CORINE LAND COVER project (DESTATIS, 1989).

7.2.2 Methodological issues (5.B)

7.2.2.1 Data sources

The following data sources were used for determination of cropland areas, for determination of any land-use changes, for allocation of natural and administrative parameters, for development of emission factors for soils and biomass and for calculation of carbon stocks in soils and biomass at various times (for literature details, cf. Chapter 14.5.2.1/14.5.2.2 in the Annex):

1. Digital soil map of Germany, drawn to a scale of 1: 1 000.000 (BUEK 1000)
2. CORINE LAND COVER
3. Data from the following official German statistics:

- Main soil-use survey (Bodennutzungshaupterhebung) 1991, 1999, 2001
- Area survey (Flächenerhebung) 1993, 1997, 2001
- Data from the district reform of 1998
- Data from the Federal Forest Inventory (Bundeswaldinventur)

For determination of emission factors

Soil:

- Literature

Biomass:

- Main soil-use survey (Bodennutzungshaupterhebung) 1999
- Statistical Yearbook (Statistisches Jahrbuch) (BMVEL 2003)
- Literature

The procedures for determining outset parameters, as well as land areas and usage changes, are described in detail in the Annex, Chapter 14.5.2.1/14.5.2.2. The net changes between 1991 – 1999 and 1999 – 2001 were determined. More recent data is not available. The data was normed using data from the 2001 area survey (Flächenerhebung). A model was applied to these net changes in order to estimate the area changes resulting from use changes (for a detailed description, cf. also Chapter 14.5.2.1 in the Annex). To the thusly determined areas, it was then possible to assign directionality for the use changes – and this, in turn, made it possible to use emission factors for soil and biomass, as derived from the literature, (cf. also Chapter 14.5.2.3 in the Annex) to estimate carbon-stock changes in soil and biomass. All land-use changes that did not lead to grassland or forest were then combined, in the category "Other land" (CRF 5.F), since it was not possible to classify the relevant follow-on uses. It was assumed that no CO_2 emissions or storage occur. N_2O emissions resulting from the conversion of grassland, fallow land, permanent cultivations and forest land to cropland (CRF Table 5 (III)) were determined in accordance with Chapter 3.3.2.3.1.1 GPG (2003).

7.2.2.2 Mineral soils

The change in carbon stocks in mineral soils – changes which are expected only in connection with land-use changes – was calculated on the "rural district" aggregation level, via formation of the difference between the final carbon stock (following the usage change) and the initial carbon stock (prior to the usage change) for the relevant area. The final carbon stock was determined by multiplying the area affected by a usage change with the weighted carbon stock – corrected via an emission factor – for the relevant land-use class. The equation is as follows:

$$\Delta C = C_f - C_i = A * EF * C_{gew.} - A * C_{gew}$$

where:

Δ C: Change in the carbon stocks as a result of usage change in t/district*monitoring period

C_f: Final soil carbon stocks in t

C_i: Initial soil carbon stocks in t

A: Area on which land-use change has occurred, in ha

EF: Dimensionless emission factor

C_{gew}: Weighted rural-district-specific and use-specific carbon stocks in t/ha (derived from BUEK 1000, CORINE, BOHE and FE)

The results calculated according to this equation can be used to derive new, weighted soil carbon stocks, broken down by usage categories, as initial values for the next period considered. This is done by dividing the rural districts' soil carbon stock that was newly calculated for each usage category by summation, by the relevant "new" area sum.

7.2.2.3 Organic soils

The carbon-stock differences for organic soils were estimated on the basis of values from the literature. MUNDEL (1976), GENSIOR und ZEITZ (1999), MEYER (1999) und AUGUSTIN (2001) report losses in grassland areas ranging from 2.46 – 7.63 t C $ha^{-1}a^{-1}$, and HÖPER (2002) reports a range of 4.6 – 16.5 t C $ha^{-1}a^{-1}$, with bogs used as cropland reaching 10.6 – 16.5 t C $ha^{-1}a^{-1}$. For the report, a grassland emission factor of 5 t C $ha^{-1}a^{-1}$, and a cropland emission factor of 11 t C $ha^{-1}a^{-1}$, were defined from these sources. The uncertainty, and the minimal and maximal values, result from the range of the above-cited values.

7.2.2.4 Biomass

The carbon-stock changes in biomass are estimated by subtracting the biomass carbon stock before the use change from the stock after the use change, with reference to the area affected by the change:

$$\Delta C_{Bio} = C_{Bio}f - C_{Bio}i = A * EF_{final} - A * EF_{initial}$$

ΔC_{Bio}: Change in the biomass carbon stocks in t/district*monitoring period

$C_{Bio}f$: Final biomass carbon stocks in t

$C_{Bio}i$: Initial biomass carbon stocks in t

A: Area on which land-use change has occurred, in ha

EF_{final}: Plant-specific biomass carbon stocks in t/ha (after use change)

$EF_{initial}$: Plant-specific biomass carbon stocks in t/ha (before use change)

Biomass carbon stocks were mathematically combined pursuant to GPG-LULUCF (IPCC, 2003) (cf. Chapter 14.5.2.3.2) in the Annex).

The values for 1990, 2002, 2003 and 2004 were linearly extrapolated, under the assumption that land-use changes and area changes would be in keeping with those of neighbouring years.

7.2.3 Uncertainties and time-series consistency (5.B)

The largest uncertainties are caused by the procedure for determining land-use changes on the basis of net area changes for individual land-use categories, over long periods of time. A preliminary review showed that the actual usage changes were clearly underestimated; in the case studied, the changes were actually greater by a factor of 60 – 100.

The potential error in estimation of carbon losses from the soil is about 70% of the mean value. The curve adjustments for determination of emission factors are highly significant; they explain 93.6 % (grassland/forest/untilled land to cropland) and 68.2 % (cropland to grassland/forest/untilled land) of the variation (cf. Chapter 14.5.2.5.2).

Although the statistical surveys for determination of land-use categories and their relevant areas are carried out regularly (complete surveys every four years), the time series are not unequivocally consistent. The reasons for this are as follows:

- German reunification in 1990; as a result, surveys for Germany as a whole do not begin until 1991 (BOHE) and 1993 (FE).
- Repartitioning of areas / district reform (1993/1998).
- Not all German Länder survey all parameters at all survey dates.
- The survey frequencies of some German Länder deviate from the basic relevant principle.

As a result of these factors, some of the data in published tables does not support comparisons (examples include combination of data from different years, and use of non-comparable reference areas (such as the administrative unit in a case in point)). Furthermore, the parameters presented throughout the various relevant formats vary; in particular, phasing-in of electronic data provision has led to a reduction of parameters and to form changes in them. As a result, unless certain Länder provide additional information, and unless certain data is modified and normed, a number of surveys will not lend themselves to comparisons.

A standard algorithm has been used to adjust and norm the data sources, for all report years; this has ensured that the values entered into the CRF tables are consistent. Since no data is available for 1990 for the new German Länder, the reconstruction for 1990 is based on the assumption that the conditions prevailing in 1991 also prevailed in that year. For identification of the land-use categories for 2002, 2003 and 2004, the BOHE 2003 survey data had not been available up to the time the report went to press. For this reason, it was assumed that the relevant changes were similar to those in the preceding years (cf. also Chapter 14.5.2.6 in the Annex).

Because of the method used for N_2O estimation, the errors which occurred in determining carbon stocks will propagate. Use of the default method, based as it is on assumptions in need of scientific improvement, additionally increases the uncertainty.

It is not currently possible to quantify the uncertainties, as all parameters actually affecting the formation and release of N_2O vary greatly across area and are not used for determination, in keeping with GPG (2003).

7.2.4 Source-specific quality assurance / control and verification (5.B)

With the exception of "Institutionalisierung der Datenbereitstellung" ("Institutionalisation of Data Provision"), the data sources used to prepare this inventory fulfill the checking criteria of the QSE manual for data sources (and yet are still inadequate; cf. Chapter 14.5.2.6). No special third-party QA/QC checking is carried out. The activity and liming data were taken from statistics based on federal laws that, as a rule, feature high-quality specification. The general relevant principles include neutrality, objectivity and scientific independence. The affected parties are required by law to provide truthful, complete information.

7.2.5 Source-specific recalculations (5.B)

This year's report presents revised tables for all years since 1990, as some of the values in Tables 5.B.1 “cropland remaining cropland” and 5.C.1 “grassland remaining grassland” differed slightly from the calculated values because of transfer errors. In addition, N_2O emissions resulting from conversion to cropland were estimated for the first time and added for the years before 2004. The correction of the data means that the tables are now consistent and virtually complete (hedges and woodland patches, which are not covered by the definition of “forest”, remain excluded).

7.2.6 Planned improvements (source-specific) (5.B)

Intensive work was undertaken last year to implement the measures cited in the NIR 2005 to improve carbon inventories in subsequent years. Due to equipment and licensing problems, and the fact that there are still considerable deficiencies in data flow, the results of these efforts are not yet reflected in this year’s report, although the requisite systems have been developed. The improvements concerned include, in particular, complete GIS-based identification of land-use changes through the use of area-referenced data such as ATKIS and InVeKoS (the latter have undergone initial integration testing). In addition, work has begun to review models used to calculate carbon stock changes and N_2O flows (tests are being carried out using DNDC = DeNitrification-DeCompostation).

The following improvements are planned to be implemented next year:

- GIS-based use of ATKIS, and possibly of some InVeKoS data sets for identification of land use and land-use changes
- Use of an improved soil map based on the profiles database for the map of the humus concentrations in Germany's soils
- Improvement in the E factors used for soils, particularly for wet, organic soils
- Review of models used to calculate carbon-stock changes and N_2O flows in soils
- Use of more precise values for carbon stocks in perennials (fruit trees, grapevines)
- Use of more precise values for carbon stocks in underground biomass
- Resolving licensing problems and provision of relevant technology.

For further remarks, cf. Chapter 14.5.2.6 in the Annex.

7.3 Grassland (5.C)

The anthropogenic CO_2 emissions from grassland were placed at 16,598 Gg for the year 2004. A total of 16,670 Gg of CO_2 emissions were released from drainage of organic grassland soils, and 998 Gg were stored through conversion of cropland into grassland. The loss of above-ground biomass corresponded to 859 Gg of CO_2 equivalents. With regard to the relevant uncertainties and liming, cf. Chapter 7.2 (CRF 5.B) and Chapters 14.5.2.4 and 14.5.2.6 in the Annex.

7.3.1 Source-category description (5. C)

Gas	CO_2	CH_4	HFCs	PFCs	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)	CS/D									
EF uncertainties in %										
Distribution of uncertainties										
Method of EF determination	CS/T2[230]									

The source category "Grassland" has not yet been subjected to key-source analysis.

Pursuant to GPG LULUCF (IPCC, 2003), reporting under the category "grassland" includes reporting on carbon-stock changes in soil and biomass stocks. The land area subsumed under "grassland" consists of:

- Permanent grassland
- Untilled land

Reporting under "grassland" is based on definitions for the usage-type key of the Working group of surveying administrations of the Länder of the Federal Republic of Germany (Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder der Bundesrepublik Deutschland - AdV), in the "Directory of area-based usages in the property cadastre and their definitions" ("Verzeichnis der flächenbezogenen Nutzungsarten im Liegenschaftskataster und ihrer Begriffsbestimmungen" - AdV, 1991), and on the "Ground-cover nomenclature" ("Nomenklatur der Bodenbedeckungen") of the CORINE LAND COVER project (DESTATIS, 1989).

7.3.2 Methodological issues (5. C)

Cf. Chapter 7.2.2

7.3.3 Uncertainties and time-series consistency (5. C)

Cf. Chapter 7.2.3

7.3.4 Source-specific quality assurance / control and verification (5. C)

Cf. Chapter 7.2.4

7.3.5 Source-specific recalculations (5. C)

Cf. Chapter 7.2.5

7.3.6 Planned improvements (source-specific) (5. C)

Cf. Chapter 7.2.6

7.4 Wetland (5.D)

Emissions from this source category are currently not being reported.

7.4.1 Source-category description (5. D)

7.4.2 Methodological issues (5. D)

7.4.3 Uncertainties and time-series consistency (5. D)

7.4.4 Source-specific quality assurance / control and verification (5. D)

7.4.5 Source-specific recalculations (5. D)

7.4.6 Planned improvements (source-specific) (5. D)

7.5 Settlements (5.E)

Emissions from this source category are currently not being reported.

7.5.1 Source-category description (5. E)

7.5.2 Methodological issues (5. E)

7.5.3 Uncertainties and time-series consistency (5. E)

7.5.4 Source-specific quality assurance / control and verification (5. E)

7.5.5 Source-specific recalculations (5. E)

7.5.6 Planned improvements (source-specific) (5. E)

7.6 Other land (5.F)

7.6.1 Source-category description (5. F)

To source category 5.F, all those areas have been assigned that do not belong in the categories forest, cropland or grassland; pursuant to GPG LULUCF (IPCC, 2003), therefore, this includes settlement areas, wetlands and other lands (cf. Chapter 7.2.2.1).

In the case of agricultural reporting, it is assumed that land-use changes to and from source category 5.F are CO_2-neutral overall (cf. Chapters 14.5.2.1 & 14.5.2.2).

In CRF category 5.F.2.1 "Forest land converted to other land", all conversions of forest to (any) other land uses are reported as an aggregated value, without any differentiation.

The areas in question have been cumulated since the key year for the first Federal Forest Inventory (1987). With the available data, it is not possible to list the cumulated area from the relevant last 20 years, as called for by the IPCC Good Practice Guidance for Land use, Land-use change and Forestry (IPCC, 2003). The stock loss from biomass has been interpolated between 1987 and 2002 and refers, in each case, only to the report year. The reduction in the "implied emission factor" thus does not represent a real trend; it results from the fact that the reference area has increased from year to year.

Annual conversions to cropland and grassland, reported in categories 5.B and 5.C, were deducted in order to prevent double counting.

With the available data from the two Federal Forest Inventories, it was possible to derive data on deforested areas, and the relevant biomass losses, only for the old German Länder since

1987, the key year for Federal Forest Inventory I (BWI I); the actual area and stock changes are thus underestimated. For the new German Länder, only estimates on net increases of forest area are available (cf. Chapter 7.1.2.2.1).

Forest areas converted to other forms of land use are smaller overall than the new forest areas. At the same time, they had higher average biomass stocks prior to conversion. In conversion, such stocks are normally removed, and thus they are considered C emissions.

The C-stock losses from dead wood, debris and soil, and relevant emissions of other greenhouse gases, cannot be precisely determined. The CRF tables thus contain only the C losses from tree biomass.

7.6.2 Methodological issues (5. F)

7.6.2.1.1 Deforested land

The total deforested area in the old German Länder (not including the non-wooded ground) is about half as large (67.33 kha and 4.49 kha/a) as the new forest area. The corresponding figures for the new German Länder cannot be derived from the available data.

7.6.2.1.2 Stock losses, deforestation areas

In the old German Länder, individual-tree-based extrapolation was carried out for this category (cf. 7.1.1.2.3). The C emissions that must be assigned to these areas are higher, as a result of their stock accumulations, than C binding by new forest lands. All in all, total stocks of 4,035 Gg C were lost from biomass in this category. Applying linear interpolation, this corresponds to an annual loss of 269 Gg C. For the sake of simplicity, it was assumed that these C stocks are emitted into the atmosphere as carbon dioxide in the year in which they are converted. Carbon binding by vegetation that succeeds the forest was estimated only for one follow-on use – "cropland" (cf. CRF 5.B). Such binding is nearly negligible and is not included in the net emissions from forest conversion reported as memo items in CRF 5.

As to C-stock losses from dead wood, debris and soil, only a first, very rough estimate, based on average stocks identified by the Federal Forest Inventory (BWI) and the soil-condition survey (BZE), can be provided. The results (cf. Annex, Table161) are reported as a memo item, but they have not been included in the CRF tables.

The total emissions from these areas could be more precisely estimated by linking the relevant BWI points with soil maps or with the nearest BZE points.

Stock losses from deforestation cannot be calculated for the new German Länder.

7.6.3 Uncertainties and time-series consistency (5. F)

7.6.4 Source-specific quality assurance / control and verification (5. F)

7.6.5 Source-specific recalculations (5. F)

7.6.6 Planned improvements (source-specific) (5. F)

7.7 Other areas (5.G)

Emissions from this source category are currently not being reported.

7.7.1 Source-category description (5. G)

7.7.2 Methodological issues (5. G)

7.7.3 Uncertainties and time-series consistency (5. G)

7.7.4 Source-specific quality assurance / control and verification (5. G)

7.7.5 Source-specific recalculations (5. G)

7.7.6 Planned improvements (source-specific) (5. G)

8 WASTE AND WASTE WATER (CRF SECTOR 6)

8.1 Solid waste disposal on land (6.A)

CRF 6.A					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 - contribution to total emissions**	**2004 - contribution to total emissions**	**Trend**
6.A.1 Solid waste diposal on land	l / t	CH_4	2,83 %	1,08 %	falling

Gas	CO_2	CH_4	HFC	PFC	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)		CS/D								
EF uncertainties in %										
Distribution of uncertainties										
Method of EF determination		T2								

The source category "Solid waste disposal on land" (6.A) is a key category in terms of both emissions level and trend.

Only managed disposal in landfills (6.A.1) is relevant for purposes of German emissions reporting under CRF 6.A. "Wild" or illegal dumping of solid waste (CRF 6.A.2) is prohibited by law in Germany.

Other methods of treating biodegradable waste fractions have been gaining in importance. As a result, this report also covers, for the first time, emissions from composting. These emissions are reported under category 6.D Other.

In the CSE, source category 6.A Solid waste disposal on land includes landfilled household waste and sewage sludge.

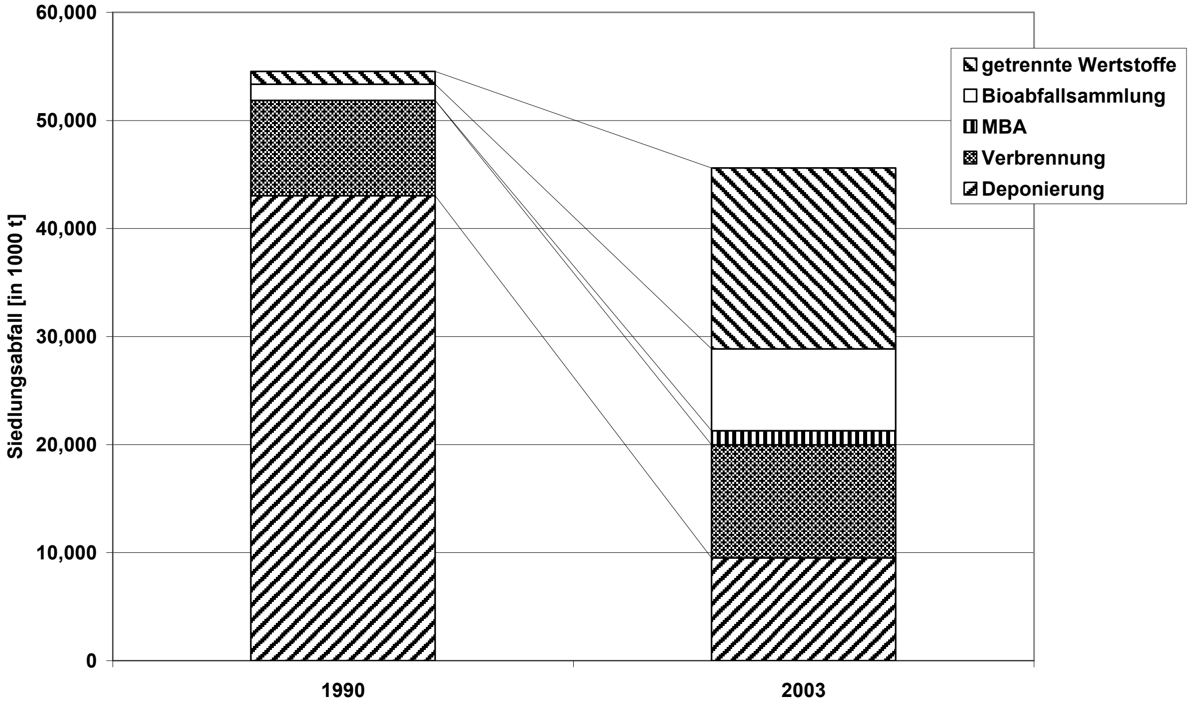
Figure 52: Structural allocation, 6.A Sold waste disposal on land

8.1.1 Managed disposal in landfills – landfilling of municipal waste (6.A.1)

8.1.1.1 Source-category description (6.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 municipal waste has been expanded, and mechanical-biological treatment of residual waste has been introduced. As a result of such measures, amounts of landfilled municipal waste decreased by nearly 80% from 1990 to 2003 (see Figure 53). As the figure shows, about half of municipal waste produced in Germany today is collected separately and gleaned for recyclable materials (separate collection of recyclable materials and biodegradable waste).

Figure 53 Changes in pathways for management of household waste, 1990 to 2003



[Municipal waste [in thousands of tonnes]; Separated recyclable materials; Collection of biological waste; Mechanical-biological treatment (MBA); Incineration; Landfilling]

In the year covered by the report, about 400 landfills for municipal waste were in operation in the Federal Republic of Germany. Strict legal regulations are in place that require such landfills to have equipment for collecting and treating landfill gas; these regulations have extensively reduced methane emissions from such facilities. As a result of new, more extensive requirements imposed by the Ordinance on waste storage and on landfills (Abfallablagerungs- und der Deponieverordnung), about ⅔ of these landfills will close by June 2005. As of that time, no further landfilling is permitted of waste that has a loss by combustion of greater than 5 % by weight.[63] In other words, landfilling of waste with significant potential for methane formation will no longer be permitted in future. For conformance with pertinent requirements, municipal waste must be pre-treated via thermal or mechanical-biological processes. Pre-treatment will reduce stored waste amounts, in comparison to their 2003 levels, by an additional 60 - 70 % in future. As landfill-gas formation from older landfill storage layers tapers off, landfill methane emissions will again decrease

63 As of 2005: Landfill class I: little or no gas formation; landfill class II: moderate gas formation, except for formation in mechanical-biological landfill facilities, of which only a few are in operation to date (sub-report waste / waste water F+ E 299 42 245).

extensively, and thus methane emissions in 2012 are expected to be less than 10 % of the methane emissions of 1990.

8.1.1.2 Methodological issues (6.A.1)

The *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC et al, 1997) specify two methods for determining methane emissions from landfills, a default method (Tier 1), known as the "mass-balance approach", and the "first order decay method" (short name: "FOD method" or "Tier 2"). Whereas the default method functions under the assumption that methane from waste forms completely in the year in which the waste is placed in a landfill, the FOD method uses a kinetic approach that describes methane formation, more realistically, as taking place over several years.

There are several reasons why the Tier 1 method is inadequate for determining emissions in Germany:

- IPCC *Good Practice Guidance* (IPCC, 2000) specifies that the first order decay method should be used when source category 6.A is a key category. At present, this source category is a key category in Germany in terms of emissions levels and trend.

The default method tends to underestimate emissions especially when quantities of waste being placed in landfills are decreasing, and this is occurring in Germany. For this reason, in the following section, CH_4 emissions were calculated with the FOD method (Tier 2).

The following section describes the FOD method, and the relevant parameters used, for determining methane formation in landfills. The FOD method calculates in accordance with Equation 18:[64]

Equation 18

$$CH_4 \ produced \ in \ year \ t \ (Gg/year) = \sum_x [(A * k * MSW_T(x) * MSW_F(x) * L_0(x) * e^{-k(t-x)}]$$

$$where: L_0(GgCH_4/kg \ waste) = MCF * DOC * DOC_F * F * 16/12$$

$$for \ x = first \ year \ to \ t$$

where:
t = inventory year
x = year in which consideration begins and quantity data is collected
MSW_T (x) = Total quantity of municipal waste
MSW_F (x) = Percentage of municipal waste that is landfilled
$A = (1-e^{-k})/k$ = Normalisation factor for sum correction
k = Constant methane-formation rate (1/year)
L_0 = Potential methane formation
MCF (x) = Methane-correction factor for year x
DOC (x) = Degradable organic carbon in year x (percentage)
DOC_F = Proportion of DOC converted into landfill gas
F = proportion of CH_4 in landfill gas
16/12 =Factor for conversion from C to CH_4

A multi-phase model was used that calculates with a range of different half-lives for the various waste fractions involved.

64 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 et al 1997), and in the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, known as the "Good Practice Guidance" (IPCC 2001).

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 19:

Equation 19

$$CH_4 \text{ emitted in year t (Gg/year)} = (CH_4 \text{ produced in year t} – R(t)) \bullet (1- OX)$$

Where
R(t) = CH_4 collection in year t
OX = Oxidation factor (proportion)

For both Tier 1 and Tier 2, the relevant quantities of municipal waste (MSW_T), and the proportion of settlement waste that is landfilled (MSW_F), must be determined; for Tier 2, production of municipal waste over the previous decades must also be determined. Pursuant to IPCC Good Practice Guidance (2000), landfilled municipal waste should be broken down – via estimation – into waste types, since the further procedure takes account of the fact that different waste types have different DOCs.

8.1.1.2.1 Quantities of landfilled waste

The FOD model calculates emissions from municipal waste, industrial waste and landfilled sewage sludge.

Pertinent quantities of landifilled municipal waste (household and commercial waste) are taken from relevant statistics of the Federal Statistical Office (DESTATIS, 1975-2002), 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 equipment of the facilities. The data for 2003 and 2004 was extrapolated on the basis of a linear regression covering the 1996 – 2002 period. Statistical surveys for the years 2003 and 2004 were not published until the second half of 2004 and were not available for the present report. The surveys of landfilled quantities of municipal 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 municipal waste, differentiated by Länder, is available for the years 1990 and 1993. For the 1980s in the former GDR, Lale (2000) has presented data that provides 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 former GDR, at 190 kg/person, were considerably lower than the corresponding quantities in the old German Länder (330 kg / person and year). This has to do with the fact 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 the following industrial sectors:

- 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
- 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 data 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 to 1970 period have only a very marginal effect on emissions in the base year.

Data on landfilling of sewage sludges from public and industrial wastewater treatment is available for the old German Länder for the period since 1975. This data has been extrapolated via population data (public wastewater treatment), under the assumption that quantities of sewage sludge (industrial waste) remained constant. Here as well, changes in assumptions regarding industrial quantities for the 1950-1970 period have only slight impacts on base-year emissions, because the half-life for sewage-sludge decomposition in landfills is short – four years.

8.1.1.2.2 Waste composition

For purposes of inventory calculation, numerous studies on waste composition were evaluated to determine historical trends in waste fractions. In the years 1980 and 1985, waste composition was determined for the entire territory of the former Federal Republic of Germany (UBA 1983, 1986). For the subsequent period, a large number of individual studies exists – studies carried out by individual cities, rural 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 2004 (see Figure 54 and Figure 55). Such evaluation of existing studies was carried out for household waste, household-like commercial waste and for 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 municipal 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 as 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.

Figure 54 Trends in waste composition (old German Länder) between 1980 and 2000[65]

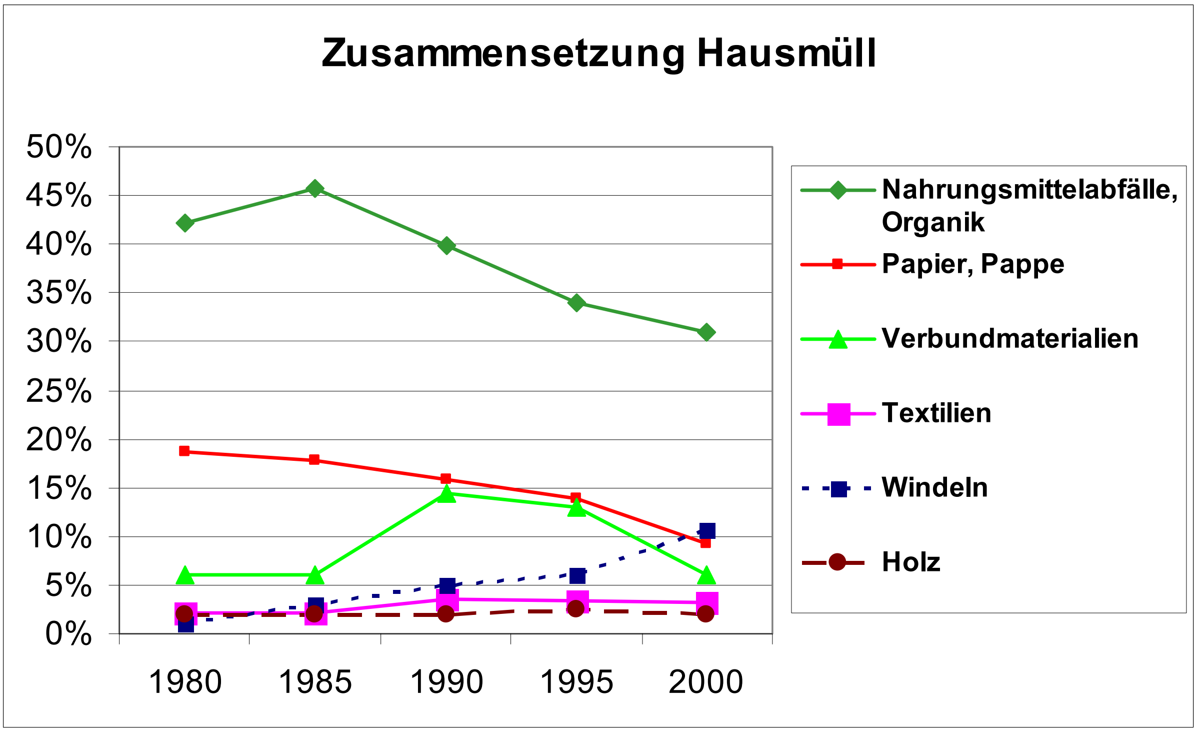
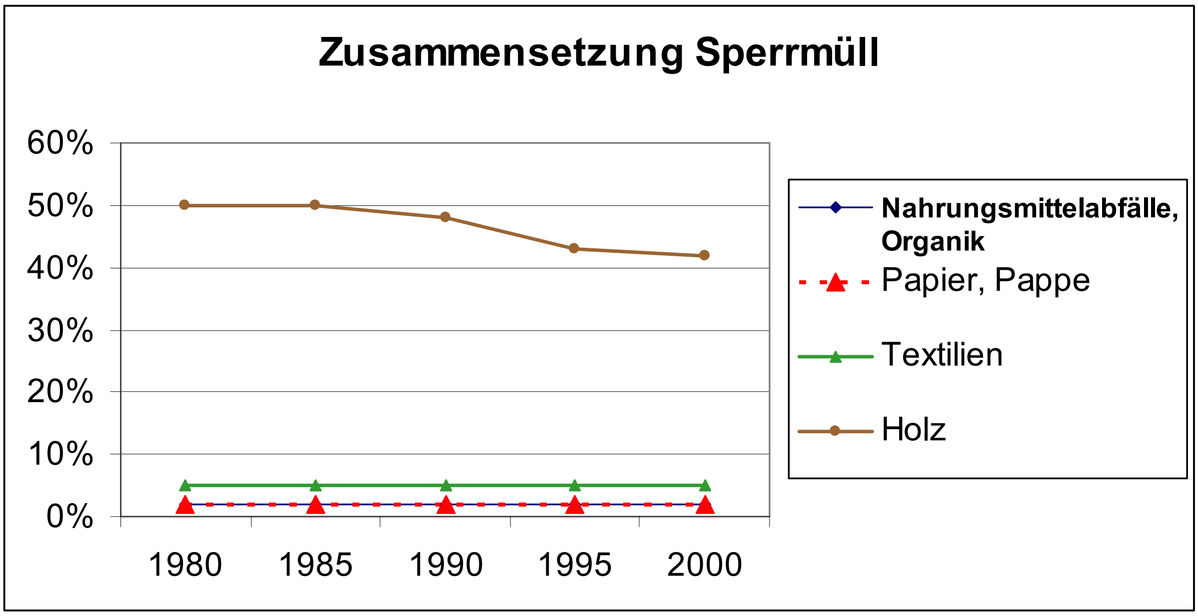


Figure 55 Trends in composition of bulky waste (old German Länder) between 1980 and 2000 [Composition of bulky waste; Food and organic waste; Paper, cardboard; Textiles; Wood]



[65] Composition of household waste: (top to bottom) Food and organic waste; Paper, cardboard; Composites; Textiles; Diapers; Wood

8.1.1.2.3 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 is available from a 1989 survey of the territory of the former GDR that covered 120 managed landfills, some 1000 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.

8.1.1.2.4 DOC

Both national data and IPCC default factors were used for DOC, the proportion of degradable organic carbon in waste. The following table provides an overview of the DOC values used.

Table 103: 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	50%	IPCC default value for sewage sludge, referenced to dry weight

8.1.1.2.5 DOC_F

DOC_F, the DOC proportion that can be converted into landfill gas, is put at 50 % for municipal waste, on the basis of a national study (RETTENBERGER et al, 1997: p. 277). This value lies within the IPCC default range of 0.5-0.6.

8.1.1.2.6 F = proportion of CH_4 in landfill gas

A value of 50%, the mean value in the IPCC default-value range, is assumed for F. This value was confirmed by a national research project (UBA, 1993).

8.1.1.2.7 Half-life

The calculation model is a multi-phase model that takes account of the different half-lives for the various different waste fractions. Table 104 shows the half-lives used for the pertinent waste fractions.

Table 104 Half-lives of waste fractions

Type of waste	Half-life (years)
Food waste	4
Garden/park waste	7
Paper / cardboard	12
Wood	23
Textiles / diapers	12
Composite materials	12
Sewage sludge	4

8.1.1.2.8 Landfill-gas use

The "TA Siedlungsabfall" of 1993[66] made gas collection one of the prerequisites for licensing of landfills for municipal waste. Collection of gas from landfills began in the 1980s (Melchior 2002); Melchior (2000) reports a gas-collection rate of 35 % for this period. To date, no detailed findings are available, at the federal level, from monitoring of gas usage from individual landfills. Landfill operators are required to report solely to Länder licensing authorities. The amended version of the Environmental Statistics Act (Umweltstatistikgesetz) of 2005 mandates that the Federal Statistical Office shall in future include and publish landfill-gas collection in its surveys, i.e. for future years it will be possible to replace this parameter with data from individual landfills. Data on gas collection in 1993 is available; it shows that 35 % of landfills were connected to a gas-collection system (UBA, 1994). In principle, collection did not begin until the 1980s. For 2004, it was assumed that gas was being collected in 95% of all landfills, and that collection efficiency amounted to 60%. For 1990, an efficiency of 45 % was assumed. These basic figures were used as a basis for calculating the amounts of CH_4 that must be deducted as a result of use of generated methane gas.

Use of landfill gas for energy recovery is recorded and reported by the energy sector. Rough conversion of the assumptions noted here, into energy data, along with a comparison with various sources of data on use of landfill gas for energy recovery, showed that the method selected leads to conservative results and that publications on status of use of renewable energies show landfill-gas use in excess of the gas quantities taken into account for recent years in category 6.A. At the same time, the data from energy statistics is not based on data from all facility operators.

8.1.1.2.9 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 accepted for the entire time series. On the one hand, a larger proportion of uncontrolled landfills can be expected in the former GDR in the early 1990s; on the other hand, a research project found only a low CH_4-formation potential for landfills of the former GDR, and thus the factor 0.1 was also used for this period (BMBF, 1997).

[66] Technical instructions on recycling, treatment and other management of municipal waste (Third general administrative provision on the Waste Act (Abfallgesetz)) of 14 May 1993

8.1.1.3 Uncertainties and time-series consistency (6.A.1)

The method's uncertainties have been estimated for the first time. The results of this experts' assessment are presented in the Annex, Chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**.

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.

8.1.1.4 Source-specific quality assurance / control and verification (6.A.1)

The selected parameters were compared with relevant data for other countries.

In the area of landfill-gas use, various national data sources were compared and a consistent, conservative approach was selected.

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 national model's parameters and data into the FOD model. The same result was obtained.

8.1.1.5 Source-specific recalculations (6.A.1)

The entire time series for CH_4 emissions from landfilling of municipal waste, for the period 1990 to 2004, was recalculated using a revised Tier 2 method. The improvements over the previous year include the following aspects:

- For the first time, industrial waste was included in the calculations.
- The picture for waste composition, which had previously been assumed to be constant throughout the period covered by the report, was improved via a waste-fraction time series, for the 1980 through 2004 period, that reflects intensified separate collection and waste recycling.
- Among waste fractions, diapers and composite materials were taken into account for the first time with national DOC values.
- The Federal Statistical Office provide additional data sources for the 1975 through 1990 period; these sources have supplanted the previously used assumptions for this period. Study of the relevant literature yielded new sources of data on waste composition and landfilling in the former GDR.
- The calculation model was converted into a multi-phase model that takes account of the different half-lives of different waste fractions. In this connection, the model's time frame was expanded; it now begins at 1950, rather than at the previously used 1970; the IPCC Guidelines consider this to be "good practice".

8.1.1.6 Planned improvements (6.A.1)

In the framework of the amendment of the Environmental Statistics Act (Umweltstatistikgesetz), as of the 2006 reporting year data is being collected and published on types of gas removal, production of resulting fuels and energy generation. At the same time, efforts are being made in this context to improve the data on landfill-gas use.

8.1.2 Other sources – landfilling of residues from mechanical-biological waste treatment (MB waste treatment) (6.A.3)

MBA landfills are landfills on which residual waste is deposited following mechanical/biological treatment. Use of mechanical/biological treatment technology has been growing since the mid-1990s. Since June 2005, some 2 million Mg of MB-waste residues have been stored per year on the basis of requirements to pre-treat municipal waste prior to landfilling. The criteria applying to MB-waste residue are outlined in the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements and on Biological Waste Treatment Facilities (AbfAblV). Requirements for MB-waste landfilling of waste stipulate that this must be done in such a way as to eliminate the need for after-care. This is defined more precisely, *inter alia*, with the formulation "virtually no landfill gas". On the whole, because residual wastes will be extensively stabilised via pre-treatment, and since regulations require that TOC content not exceed 18% of the dry mass in MBA residue, MBA landfills can be expected to have only minimal CH_4 formation. Until June 2005, records were kept of quantities of waste treated in facilities for mechanical/biological treatment, but these records do not show what quantities of MB-waste residues were landfilled. For this reason, waste treated in MBA facilities, in 2004, is still reported as part of the entire quantity of municipal waste, under category 6.A "Solid waste disposal on land", and methane emissions are calculated without regard for the very low rates of CH_4 formation in this sub-category of municipal waste; as a result, calculation of CH_4 emissions in category 6.A is conservative. CH_4 emissions from landfilling of MBA residues did not have to be calculated separately until 2005, when more reliable activity data became available for this sub-category.

8.2 Wastewater treatment (6.B)

Under source category 6.B Wastewater handling (treatment), the CSE lists wastewater quantities, treatment of sewage sludge and sewage-sludge production in wastewater treatment.

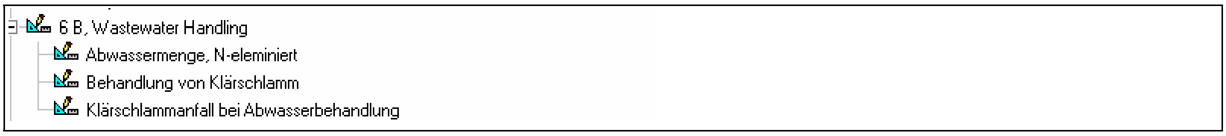


Figure 56: Structural allocation, 6B Wastewater handling (treatment)

8.2.1 Methane emissions from industrial wastewater and sludge treatment (6.B.1)

8.2.1.1 Source-category description (6.B.1)

CRF 6.B.1					
Key Category by level (l) / trend (t)		**Gas (key category)**	**1990 – contribution to total emissions**	**2004 – contribution to total emissions**	**Trend**
6.B.1 Wastewater Handling	- / t	CH_4	0.18 %	0.01 %	falling

Gas	CO_2	CH_4	HFCs	PFCs	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)	NE	D/CS	NO	NO	NO	D	NO	NO	NO	NO
EF uncertainties in %										
Distribution of uncertainties										
Method of EF determination										

In terms of its trend, the source category "methane emissions from industrial wastewater and sludge treatment" (6.B.1) is a key category.

The composition of industrial wastewater, in contrast to that of household wastewater, varies greatly, by industrial sector. In Germany, the biological stage of industrial wastewater treatment is partly aerobic and partly anaerobic. Anaerobic wastewater treatment is especially useful for industries whose wastewater has high levels of organic loads. This treatment method has the advantages that it does not require large amounts of oxygen, produces considerably smaller amounts of sludge requiring disposal and generates methane that can be used for energy recovery. As in treatment of municipal wastewater, treatment of industrial wastewater releases no methane emissions into the environment. The procedures used include aerobic treatment and anaerobic putrification; gas formed in the latter procedure is either used for energy recovery or is flared off.

Industrial sludge treatment and stabilisation, like industrial wastewater treatment, is carried out either aerobically or anaerobically with methane-gas use.

8.2.2 Municipal wastewater treatment (6.B.2)

8.2.2.1 Methane emissions from municipal wastewater treatment (6.B.2)

8.2.2.1.1 Source-category description (6.B.2)

CRF 6.B.2					
Key category by level (l) / trend (t)		**Gas (key category)**	**1990 – contribution to total emissions**	**2004 – contribution to total emissions**	**Trend**
	- / -				

Gas	CO_2	CH_4	HFCs	PFCs	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor (EF)	NE	D/CS	NO	NO	NO	D	NO	NO	NO	NO
EF uncertainties in %										
Distribution of uncertainties										
Method of EF determination										

The source category "wastewater handling, domestic and commercial" is not a a key category.

Municipal *wastewater treatment* in Deutschland – like that in Sweden and Denmark – uses aerobic procedures (municipal wastewater-treatment facilities, small wastewater-treatment facilities), i.e. it produces no methane emissions (default value for MCF = 0), since such emissions occur only under anaerobic conditions.

Treatment of human sewage from persons not connected to sewage networks or small wastewater-treatment facilities represents an exception: in cesspools and septic tanks, uncontrolled processes (partly aerobic, partly anaerobic) can occur that lead to methane formation. Since 1990, organic loads discharged into cesspools and septic tanks have been drastically reduced; the percentage of inhabitants connected to small wastewater-treatment facilities has continually increased, especially in eastern Germany.

8.2.2.1.2 Methodological issues (6.B.2)

Organic loads from cesspools and septic tanks are calculated pursuant to the IPCC method, in which the relevant population is multiplied by the average organic load per person; cf. Table108. The average organic load is assumed as 60 g BOB_5 per inhabitant. This value is the IPCC default value, on the one hand, and is used in Germany as statistical mean value, on the other.

Table108: Organic wastewater load in cesspools and septic tanks (1990-2004)

BOB_5 [kt/a] Organic loads in:	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Cesspools and septic tanks	*180,33*	172,45	*164,57*	*156,69*	*148,80*	140,92	*105,41*	*69,90*	34,38	*31,06*	*27,74*	24,42	*21,10*	*17,78*	*14,45*
of these, in western Germany	*91,69*	87,45	*83,21*	*78,97*	*74,74*	70,50									
of these, in eastern Germany	*88,65*	85,01	*81,37*	*77,72*	*74,08*	70,43									

Numbers in italics: Interpolated and extrapoled values
(DESTATIS, Fachserie 19 Reihe 2.1, 2003)

Methane emissions from cesspools and septic tanks are determined in keeping with the IPCC method. The IPCC default value for potential methane formation (0.6 kg CH_4/kg BOD_5), and an MCF of 0.5 for cesspools and septic tanks, are assumed. The MCF for cesspools and septic tanks has been estimated on the basis of experience gained other in countries (septic tanks in the U.S., anaerobically treated municipal wastewater in the Czech Republic (cf. Chapter 14.6.2). The emissions are determined as follows:

$$CH_4(cesspools\ and\ septic\ t.) = 24\ 419\ 000\ kg\ BOB_5\ x\ 0{,}6\ kg\ CH_4\ /\ kg\ BOB_5\ x\ 0{,}5$$

Table109: Methane emissions from cesspools and septic tanks (1990-2004)

Methane emissions from: [kt CH_4]	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Cesspools and septic tanks	54,10	51,74	49,37	47,01	44,64	42,28	31,62	20,97	10,31	9,32	8,32	7,33	6,33	5,33	4,34

8.2.2.1.3 Uncertainties and time-series consistency (6.B.2)

The method's uncertainties have not yet been estimated.

The activity rates for organic loads in cesspools and septic tanks are based on data from the Federal Statistical Office's Fachserie 19 Reihe 2.1, which was published in 1991, 1995, 1998 and 2001 (DESTATIS, Fachserie 19 Reihe 2.1, 2003) veröffentlicht wurde. For production of a consistent time series, the activity rates were linearly interpolated between 1991 and 1995, between 1995 and 1998 and between 1998 and 2001. The activity rate for 1990, on the other hand, was extrapolated from the 1991 to 1995 time series. The activity rates for 2002 to 2004 were extrapolated from the 1998 to 2001 time series.

Until 1995, data for the old and new Federal Länder was 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.

8.2.2.1.4 Source-specific quality assurance / control and verification

For the 2006 report, a general quality control that meets the requirements defined in the QSE manual and the associated documentation was carried out for the first time.

The MCF for cesspools and septic tanks in Germany was derived on the basis of an evaluation of national inventory reports of other countries (cf. Chapter 14.6.2).

The fact that aerobic wastewater treatment in relevant facilities produces no significant methane emissions can be confirmed in other countries (Sweden, Denmark).

8.2.2.1.5 Source-specific recalculations (6.B.2)

Extensive recalculations were reported in the NIR 2004 (UBA, 2004a). No recalculations were carried out for the present report.

8.2.2.1.6 Planned improvements (6.B.2)

Consideration is being given to carrying out a research project that would explore whether methane could indeed form in aerobic wastewater treatment, under certain conditions and in certain process steps.

8.2.2.2 Methane emissions from municipal wastewater treatment (6.B.2)

8.2.2.2.1 Source-category description (6.B.2)

As a general rule, the treatment of sewage sludge comprises two treatment stages:

- Dehydration using
  Mechanical processes (chamber-filter press, cyclone)
  Evaporation in a sludge lagoon or drying beds
- Stabilisation:
  Aerobic stabilisation (open pool with oxygen input)
  Stabilisation in digestion tower (anaerobic)
  Formerly: Open sludge digestion

With respect to population figures, mechanical *dehydration* before and after treatment in the digestion tower currently represents the main treatment method (exception: small sewage-treatment plants in rural areas). Moreover, sewage sludge is generally limed prior to subsequent use, which stabilises it still further.

Sludge stabilisation is carried out in order to prevent uncontrolled putrefaction. In facilities < 10,000 inhabitants, such stabilisation is usually carried out aerobically, with energy consumption, while for facilities > 30,000 inhabitants it it normally carried out anaerobically, with production of methane gas. The amount of methane gas produced depends especially on the composition of the sewage sludge, the temperature and the reaction conditions. Gas so produced is usually used for energy recovery in combined heat/power generating systems (CHP). 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. In both treatment methods, no significant amounts of methane emissions are released into the environment.

In the early 1990s in eastern Germany, open sludge digestion was used for sludge stabilisation, a process that produced methane emissions. Open sludge digestion is now no longer used, however.

In Germany, sewage sludge from biological wastewater treatment is managed in the following three ways (where applicable, after dehydration and stabilisation):

- Landfill storage: resulting methane emissions are reported in the waste sector.
- 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, and use in recultivation measures and in composting. Emissions from recycling for substance recovery are also not reported under wastewater and sludge treatment.

8.2.2.2.2 Methodological issues (6.B.2)

Table 110the emission factors for open sludge digestion and the methane emissions determined for that process.

Table 110: Methane emissions from open sludge digestion, in the new German Länder

	Unit	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 eastern Germany, in keeping with the results of the study FHG ISI (UBA, 1993: p.15)[67]. The activity rates for the years 1990 to 1992 were communicated personally to the Federal Environmental Agency by the Chief Inspector of the former GDR's water-processing plants.

In light of the fact that open sludge digestion is prohibited in the Federal Republic of Germany, it was assumed that use of this treatment method was gradually reduced in the new German Länder until 1994 and was no longer used at all as of 1994. On the basis of this assumption, the Federal Environmental Agency used the same activity rates – i.e. quantities of sewage sludge produced – for the years 1993 to 1994.

8.2.2.2.3 Uncertainties and time-series consistency (6.B.2)

The uncertainties for calculation of emissions from open sludge digestion in eastern Germany have not been estimated to date.

67 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.

The activity rates between 1990 and 1992 are based on a personal communication; those for 1993 and 1994, are based on estimates of the Federal Environmental Agency. As a result, a high degree of time-series consistency is not assured.

8.2.2.2.4 Source-specific quality assurance / control and verification (6.B.2)

For the 2006 report, a general quality control that meets the requirements defined in the QSE manual and the associated documentation was carried out for the first time

8.2.2.2.5 Source-specific recalculations (6.B.2)

Extensive recalculations were reported in the NIR 2004 (UBA, 2004a). No recalculations were carried out for the present report.

8.2.2.2.6 Planned improvements (6.B.2)

At present, improvements seem neither necessary nor possible, since no further activity data can be obtained.

8.2.2.3 Nitrous oxide emissions from municipal wastewater (6.B.2)

8.2.2.3.1 Source-category description (6.B.2)

Nitrous oxide (laughing-gas) emissions can occur as an auxiliary product of municipal wastewater treatment, especially in connection with denitrification, in which gaseous end products – mainly molecular nitrogen – are formed from nitrate (AUST, no year).

8.2.2.3.2 Methodological issues (6.B.2)

Pursuant to the IPCC method, nitrous oxide emissions from household wastewater can be roughly determined via the average per-capita protein intake. The IPCC default values are used in each case for the nitrous-oxide emission factor per kg of nitrogen in wastewater, and for the nitrogen fraction in protein; the average per-capita protein intake and relevant population figures for Germany have to be determined on a Länder-specific basis.

Average protein intake per person and day:

- The 1991 food table for practical applications (SENSER et al, 1991) lists an average protein intake of 94 g/inhabitant and day.
- The nutrition report of the German Nutrition Association (Deutsche Gesellschaft für Ernährung - DGE, 2000)[68] used estimated food-consumption data for 1993 to estimate average daily protein intake (among other figures). From this data, an average value of about 76.5 g protein/person and day[69] was derived.
- The FAO determined the average protein intake in Germany, per person and day, to be between 91g and 98 g (cf.Table 111). [70]

The FAO database is used for determination of the N_2O emissions from wastewater, since that database is a consistent, internationally comparable time series. The Federal Environmental Agency has no information to the effect that the Länder-specific values in the

68 The nutrition report is published every four years.
69 This value was obtained with the help of the rough estimate that each population group in Germany consists of 50% men (81.5 g/day) and 50% women (71.6 g/day).
70http://faostat.fao.org/faostat/form?collection=FS.NonPrimaryLivestockAndProducts&Domain=FS&servlet=1&hasbulk=&version=ext&language=EN and Email correspondence with FAO (27.10.2003).

food table and in the 2000 nutrition report are more precise or enjoy greater national acceptance.

Table 111: Daily protein intake per person in Germany

	[g/inhabitant and day]														
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Protein intake	98	97	96	92	95	94	96	91	96	96	96	98	98	*97*	*97*

Numbers in italics: Extrapolated or value

(FAO, no year)

Table 112: Population of Germany (1990-2004)

	[in 1000]														
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Inhabitants	79.753	80.275	80.975	81.338	81.539	81.817	82.012	82.057	82.037	82.163	82.260	82.440	82.537	82.532	82.501

(DESTATIS, 1991-2005)

The nitrous oxide emissions can be determined with the aid of Table111 and Table 112 and the IPCC method; cf.Table 113.

$$N_2O_{(s)} = Protein\ x\ Frac_{NPR} x\ NR_{PEOPLE} x\ EF_6$$ dabei:

$$N_2O_{(s)} = N_2O\ Emissions\ in\ human\ wastewater\ (kg\ N_2O - N/a)$$
$$Protein = annual\ \ protein\ cons.(kg/person/a)$$
$$NR_{PEOPLE} =\ \ population\ of\ \ the\ country$$
$$EF_6 = emission\ \ factor\ (Default\ 0.01\,(0.002 - 0.12)\ kg\ N_2O - N/kg\ \ produced\ wastewater - N)$$
$$Frac_{NPR} = nitrogen\ \ fraction\ in\ \ protein\ (default = 0.16\ kg\ N/kg\ \ protein)$$

Table113: Nitrous oxide emissions in Germany pursuant to IPCC method

	[t N_20]														
N_20 emissions	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
	7.173	7.146	7.134	6.867	7.109	7.058	7.225	6.853	7.228	7.239	7.247	7.414	7.423	7.347	7.344

(ÖKO-INSTITUT, 2004b)

8.2.2.3.3 Uncertainties and time-series consistency (6.B.2)

The uncertainties in emissions determination have not yet been estimated. The activity rate for 2003 was extrapolated from the 1999 to 2002 time series. It was used as activity rate for 2004.

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.

8.2.2.3.4 Source-category-specific quality assurance / control and verification (6.B.2)

For the 2006 report, a general quality control that meets the requirements defined in the QSE manual and the associated documentation was carried out for the first time

Analysis of the national inventory reports of other countries shows that most Annex I countries, like Germany, use the IPCC method for determining N_2O emissions. 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 (cf. Annex,Table 164).

Plans within the framework of quality assurance call for checking the country-specific N_2O emission factor reported in 2003 for wastewater treatment; this factor was determined in a national research project (Krauth et al, 1994) and in UBA (1993). The factor is 0.07 – 0.08 g N_2O/m^3 for wastewater treated in facilities with N elimination. While relevant research projects show that this factor applies to both municipal and industrial wastewater-treatment plants, it has not yet been scientifically confirmed.

8.2.2.3.5 Source-specific recalculations (6.B.2)

Since updated population figures are available for Germany for the period of 1990 to 2000, the resulting N_2O emissions for this period were recalculated. The relevant data is provided in Table 8a of the CRF report tables.

8.2.2.3.6 Planned improvements (6.B.2)

Review is currently underway to determine whether the FAO database (FAO, n.y.) for daily protein intake should be replaced with data from the nutrition report (DGE, 2000), since the latter is based on studies of eating habits and thus probably reflects actual protein intake more precisely.

In addition, as described under 8.2.2.3.4, the N_2O emission factor used to date, 0.07 – 0.08 g N_2O/m^3 of wastewater, is to be reviewed. If this emission factor can be confirmed – i.e. if it proves to be accurate for Germany – it will again be used in future.

8.2.3 Waste incineration (6.C.)

All waste incineration in Germany is carried out with energy inputs; for this reason, and in order to avoid double counting, the resulting emissions are reported in the energy section (CRF 1). No emissions (NO) from this energy use, therefore, are reported under 6.C.

8.2.4 Other areas (6.D.)

8.2.4.1 Other areas – Composting plants (6.D.1)

8.2.4.1.1 Source-category description

In the Federal Republic of Germany, growing proportions of biodegradable wastes are recovered in composting plants. For this reason, CH_4 and N_2O emissions stemming from composting of municipal waste in composting plants are reported in the present inventory for the first time, and a complete time series was calculated for these emissions. This category does not include the composting of individual households' garden or bio-wastes in their own gardens. These emissions are regarded as negligible, and there is no data available on the amounts composted.

8.2.4.1.2 Methodological aspects (6.D.1)

Neither the "1996 IPCC Guidelines for National Greenhouse Inventories" nor the IPCC report on "Good Practice Guidance" prescribe a method for emissions from waste composting. Therefore, a national method was developed, in which the quantities of waste composted are multiplied by emission factors obtained from a national study.

8.2.4.1.3 Activity data (6.D.1)

Surveys of waste quantities recovered in composting plants have been regularly compiled and published by the Federal Statistical Office since 1980. Since 2000, the input quantities of bio-waste and green waste (garden and park waste) and the waste quantities utilised in bio-gas and fermentation plants have been surveyed and published separately.

8.2.4.1.4 Emission factors (6.D.1)

For the area of composting, a calculation method for the gases CH_4, N_2O and NH_3 was derived in a research project of the Deutsche Bundesstiftung Umwelt (DBU 2002). The method distinguishes between bio-waste from households and green wastes.

The following emission factors were determined for bio-waste from households:

EF-N_2O = 83 g N_2O/Mg bio-waste

EF-CH_4 = 2.5 kg CH_4/Mg bio-waste

For green wastes, the same study determined the following emission factors:

EF-N_2O = 60.3 g N_2O/Mg bio-waste

EF-CH_4 = 3.36 kg CH_4/Mg bio-waste

These national emission factors were used for the relevant inventory calculations.

8.2.4.1.5 Uncertainties and time-series consistency (6.D.1)

The uncertainties for the waste quantities composted are considered very small (2%), as the data stem from a total survey, good standards are applied to the reporting and the relevant operators are interested in sound reporting. The uncertainties for the emission factors are large and are dependent upon the type of plant, waste composition, and the efficiency of the bio-filters used. Literature data from other countries shows large variations; consequently, an uncertainty of 60% for CH_4 and of at least 100% for N_2O is assumed here.

8.2.4.1.6 Source-specific recalculations (6.D.1)

This report year is the first for which the time series was calculated. Therefore, source-specific recalculations have not been carried out.

8.2.4.1.7 Planned improvements (6.D.1)

As well as composting of biodegradable municipal waste, mechanical/biological waste treatment is on the increase in Germany, due in particular to the legislation described under 6.A. MB-waste landfills are landfills on which residual waste is deposited following mechanical/biological treatment. Use of mechanical/biological treatment technology has been growing since the mid-1990s. From the year 2005 onwards, a growing volume of MB-waste residues is anticipated due to the obligation for compulsory pre-treatment of municipal wastes prior to landfilling. The criteria applying to MB-waste residues are outlined in the

Ordinance on Environmentally Compatible Storage of Waste from Human Settlements and on Biological Waste Treatment Facilities (AbfAblV). Future requirements for MB-waste landfilling of waste stipulate that this must be done in such a way as to eliminate the need for after-care. This is defined more precisely, *inter alia*, with the formulation “virtually no landfill gas”. On the whole, because residual waste will be extensively stabilised via pre-treatment, and since regulations require that TOC content not exceed 18% of the dry mass in MB-waste residue, MB-waste landfills can be expected to have only minimal CH_4 formation. Plans call for CH_4 emissions from landfilling of MB-waste residues to be calculated separately as soon as more reliable activity data is available for this sub-category. This will be the case as from the inventory report for 2005.

9 OTHER (CRF SECTOR 7)

At present, no greenhouse gas emissions are calculated for Germany which cannot be allocated to one of the envisaged source categories.

10 RECALCULATIONS AND IMPROVEMENTS

In the following section, recalculations and inventory improvements are documented that occurred between between the CRF coverage of the 2005 report year and that of the 2005 report year. Further information regarding the recalculations is provided in CRF tables Table 8(a) and Table 8(b) and in the present report's chapters on source-specific recalculations.

Pursuant to the aims of the *Good Practice Guidance*, emissions calculations should be based on the best available data, and efforts should be made to improve the inventories continuously. Consequently, each year quality control and assurance measures lead to recalculations. Recalculations become necessary when statistics are updated retroactively and the relevant changes are also adopted in the inventories. The need for recalculation also arises when more precise data is provided and when manual transfer errors are revised. In addition, a range of various specialised factors can necessitate recalculations (cf. Chapter 10.1.1).

10.1 Explanation and justification of the recalculations

10.1.1 General procedure

Apart from routine corrections of inventory data, a number of specialised factors can necessitate recalculations and improvements:

- New data and new time series become available
- The availability of the existing data source has changed
- The method previously used for the relevant source category was not consistent with the *Good Practice Guidance*
- The source category has become a key category, thus making a change of methods necessary
- New country-specific methods are available
- The relevant data has been re-processed in keeping with review results

In good practice, when methods change, the entire relevant time series should be recalculated with the same method, to ensure that the same method is used each year and old values can be suitably replaced. Where it is not possible to use the same method every year, alternative recalculation methods should be used. The following four recalculation methods are available for this purpose (IPCC Good Practice Guidance, Chapter 7):

- Overlapping method: For it to be possible to use this method, the data for calculation pursuant to the old and new methods should be jointly available for at least one year.
- Replacement method: For it to be possible to use this method, the EF and/or AR used to data should be highly similar to the newly available data.
- Interpolation method: The data previously used for recalculation is available only for a few years of the time series, and the lacking data is interpolated.
- Trend extrapolation or continued-use method: The data for the new method is not available for the beginning and/or end of the time series.

The QSE manual contains a guide to applying the above-outlined recalculation reasons. It also presents relevant examples.

10.1.2 Recalculations in the 2006 report year, by source categories

The inventories contain improvements in the following areas:

Energy:

- Changes in activity data for the new German Länder, on the basis of new facility data (1.A.1)
- New survey of limestone inputs REA (1.A)
- Survey of waste incineration (1.A.1)
- Survey of lignite drying (1.A.1)
- Disaggregation (1.A.2)
- Process combustion 1990-1995; survey of production of sinter, pig iron and cement (1.A.2)
- New survey of secondary raw materials (1.A.2)
- Transfer of emissions from 1.A.1 to 1.A.2
- Transfer of emissions from 1.A.1 and 1.A.2 to 2.C
- New consumption data for road traffic (1.A.3b)
- New survey of lubricants in the road-traffic sector (1.A.3b)
- New emission factors (1.A.3.c, 1.A.3.d)
- Methods change from 1990-1994, to improve consistency (1.A.4)
- Change in CH_4 emission factors and activity rates (1.B.1, 1.B.2)
- Addition to emissions from exploration for oil and natural gas (1.B.2)
- Addition to emissions from production and processing of acidic gas (1.B.2)
- Change in the 2000-2001 activity rate, on the basis of available statistics (1.BU.2)

Industrial processes:

- Change in the CO_2 emission factor (2.A.4)
- New survey of limestone inputs in the ceramics sector (2.A.3)
- Differentiation in the glass sector (2.A.7)
- New survey of organic carbon content in clays – brick industry (2.A.7)
- Use of a country-specific CO_2 emission factor (2.B.1)
- New survey of methanol production (2.B.5)
- New survey of soot production (2.B.5)
- New survey of transformation losses (2.B.5)
- Use of country-specific CH_4 emission factors (2.B.5)
- Change in emission factor for caprolactam production (2.B.5)
- New survey of coke burn-off from catalysts in refineries (2.B.5)
- Use of new, IPCC-conformal methods for the iron and steel sector (2.C.1)
- New survey of limestone inputs in the iron and steel sector (2.C.1)
- New survey of ferroalloys (2.C.2)
- Revision of figures for halocarbons and SF_6 (2)
- Change in method, and new survey of a relevant source (2.D.2)

Agriculture:

- Change in animal head counts for 2003 (4.A)
- Change in poultry populations – formerly from model calculations – via animal censuses (4.A)
- Improvement in methods for the areas of breeding bulls, fattening bulls, heifers, calves and dairy cows; calculation pursuant to Tier 2 (4.A)
- Improvement of methods relative to management of swine and cattle manure; calculation pursuant to Tier 2 (4.B)

- Initial survey of relevant numbers of sheep and horses (4.B)
- New method relative to N excretions (4.B)
- Survey of sewage sludge in the category of imported farm fertilisers (4D)

<u>Land-use changes and forestry:</u>

- The data was calculated in keeping with the new CRF structure, for the entire time series, and entered here as a sum value.
- Initial survey of N_2O emissions from conversion of cropland use
- Inclusion of sub-surface biomasse; improved calculation method for new German Länder (5.A.1)

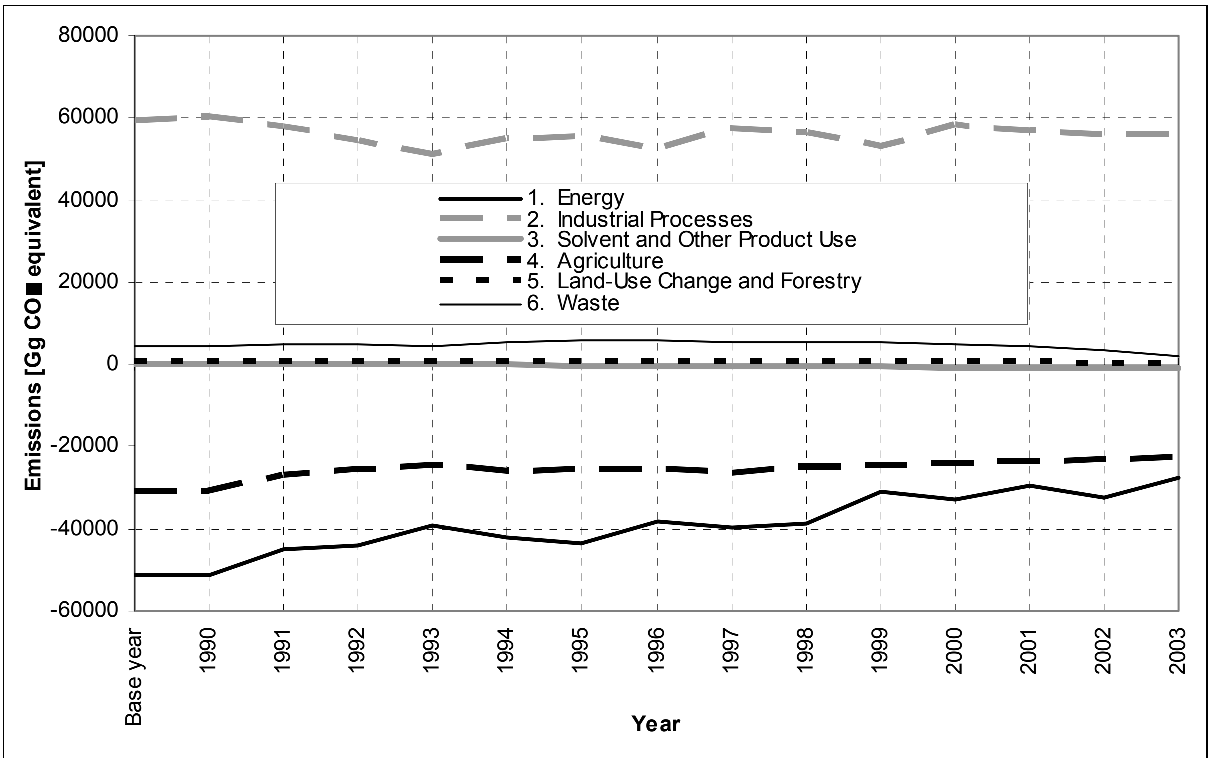


Figure 56: Change in source-category-specific total emissions, for all gases, and for the entire time series, in comparison to the relevant figures in the 2005 report

10.1.3 Recalculations in the 2006 report year, by gases

CO_2 recalculations were carried out in the following source categories:

- New determination of limestone inputs REA (1.A)
- Determination of waste incineration (1.A.1)
- Survey of lignite drying (1.A.1)
- Manufacturing industries and construction – iron and steel (1.A.2a)
- Manufacturing industries and construction – Non-ferrous metals (1.A.2.b)
- New survey of lubricants in the road-traffic sector (1.A.3b)
- Change in the activity rate for 2003 (1.A.5)
- Soda ash production (2.A.4)
- Glass production (2.A.7)
- Addition to emissions from exploration for oil and natural gas (1.B.2)
- Addition to emissions from production and processing of acidic gas (1.B.2)
- New survey of limestone inputs in the ceramics sector (2.A.3)

- New survey of organic carbon content in clays – brick industry (2.A.7)
- Ammonium production (2.B.1)
- New survey of methanol production (2.B.5)
- New survey of soot production (2.B.5)
- New survey of transformation losses (2.B.5)
- Change in emission factor for caprolactam production (2.B.5)
- New survey of coke burn-off from catalysts in refineries (2.B.5)
- Iron and steel production (2.C.1)
- New survey of limestone inputs in the iron and steel sector (2.C.1)
- New survey of ferroalloys (2.C.2)

N_2O/CH_4 recalculations were carried out in the following source categories:

- Fugitive emissions from solid fuels (1.B.1)
- Food and drink (2.D.2)
- Oil and natural gas (1.B.2)
- Chemical industry (2.B.5)
- Road transportation (1.A.3b)
- Railways (1.A.3.c)
- Navigation on inland waterways (1.A.3.d)
- Agriculture (4.)

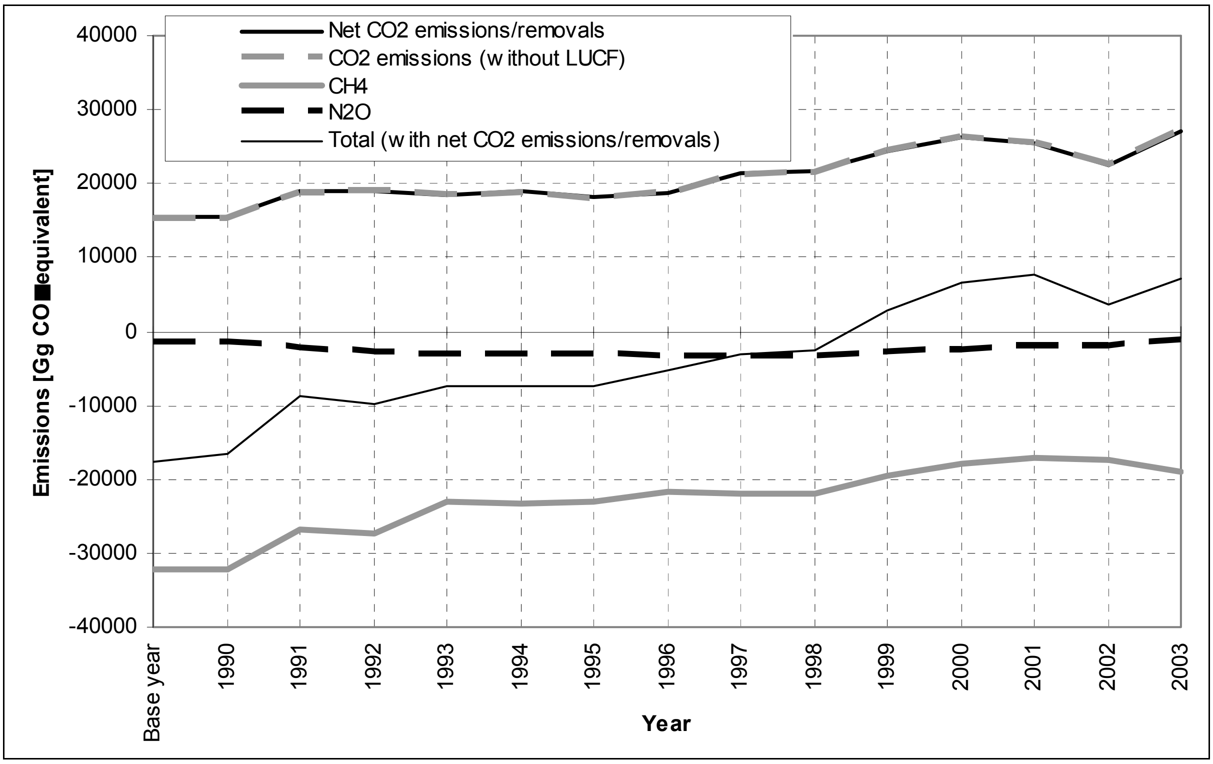


Figure 57: Change in pollutant-specific total emissions, for all source categories, and for the entire time series, in comparison to the relevant figures in the 2005 report

10.2 Impacts on emissions levels

The inventory has been considerably improved with regard to completeness and transparency. Of the recalculations made in the interest of improved transparency, those whose values were previously reported as "IE" have no impact on emissions levels.

Transfers of emissions from 1.A.1 and 1.A.2 to 2.C produced no changes in emissions. New surveys of secondary fuels, waste incineration, limestone inputs in the iron and steel sector and transformation losses have led to major emissions increases. Use of improved methods in the agriculture sector have led to significant emissions reductions.

CO_2 emissions for 1990 increased by 1.57 %, while CH_4 emissions decreased by 24.25 % and N_2O emissions decreased by 1.86 %. More detailed pertinent information is available in CRF tables 8(a)s1 and 8(a)s2. The total emissions for 1990 decreased by 1.37%.

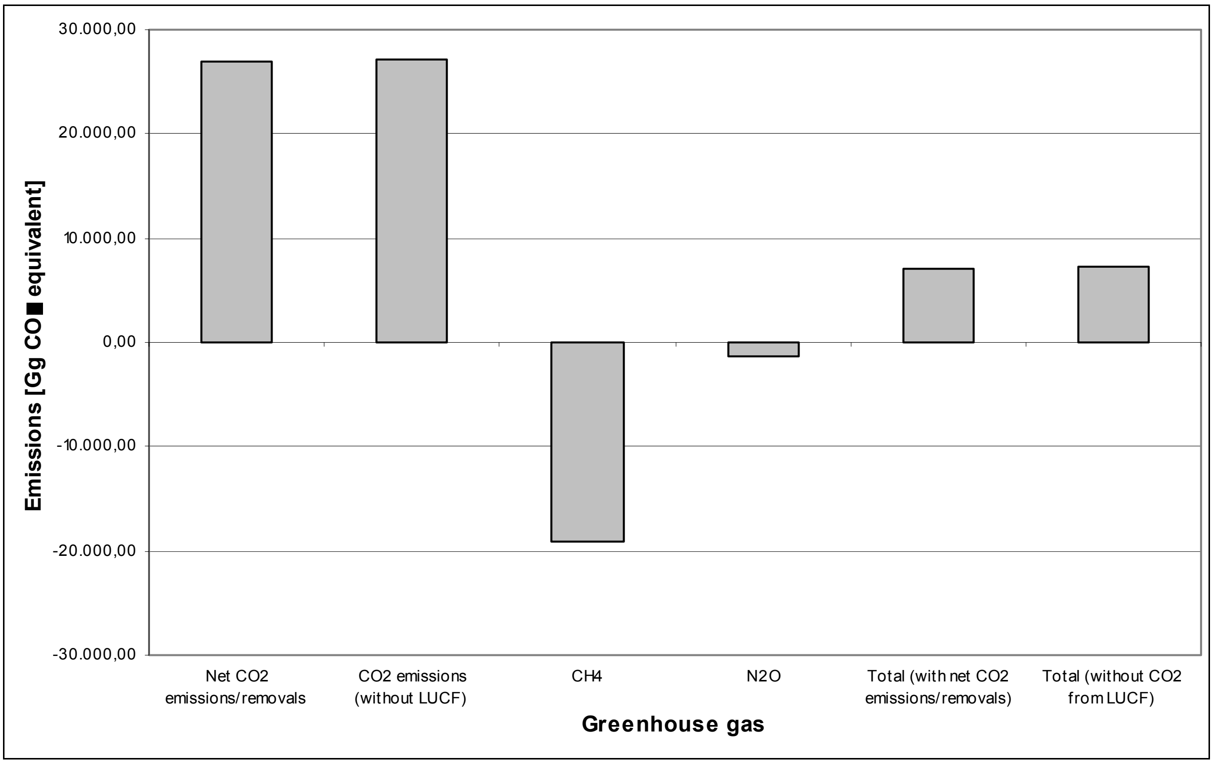


Figure 58: Recalculation of pollutant-referenced total emissions in the 2006 reporting year, for all source categories, in comparison to the corresponding figures for the 2005 report; the reference for all figures is 2003

10.2.1 Impacts on 1990 emissions levels

In comparison to the 2005 submission, total emissions for 1990, not including LUCF, changed by – 2.5%.

Recalculations of emissions from industrial processes and energy had only a partial impact on total emissions recalculations. A large share of iron and steel production (2.C.1) was previously reported under "energy". Emissions recalculations in the agricultural sector had the largest impacts on total emissions.

Table 105: Recalculation of source-category-specific total emissions, for all gases

	Change, in CO_2 equivalents [Gg]	Change [%]	Reported 2005 [Gg]	Reported 2006 [Gg]
Total national emissions (not including LUCF)	**-17396**	**-1,4**	**1243692**	**1226296**
1. Energy	-51290	-4,9	1036617	985327
2. Industrial processes	59985	99,7	60165	120150
3. Solvent and other product use	167	8,7	1922	2089
4. Agriculture	-30768	-28,2	109070	78302
5. Land-use changes and forestry	703	2,4	-28944	-28241
6. Waste	4510	12,6	35918	40429

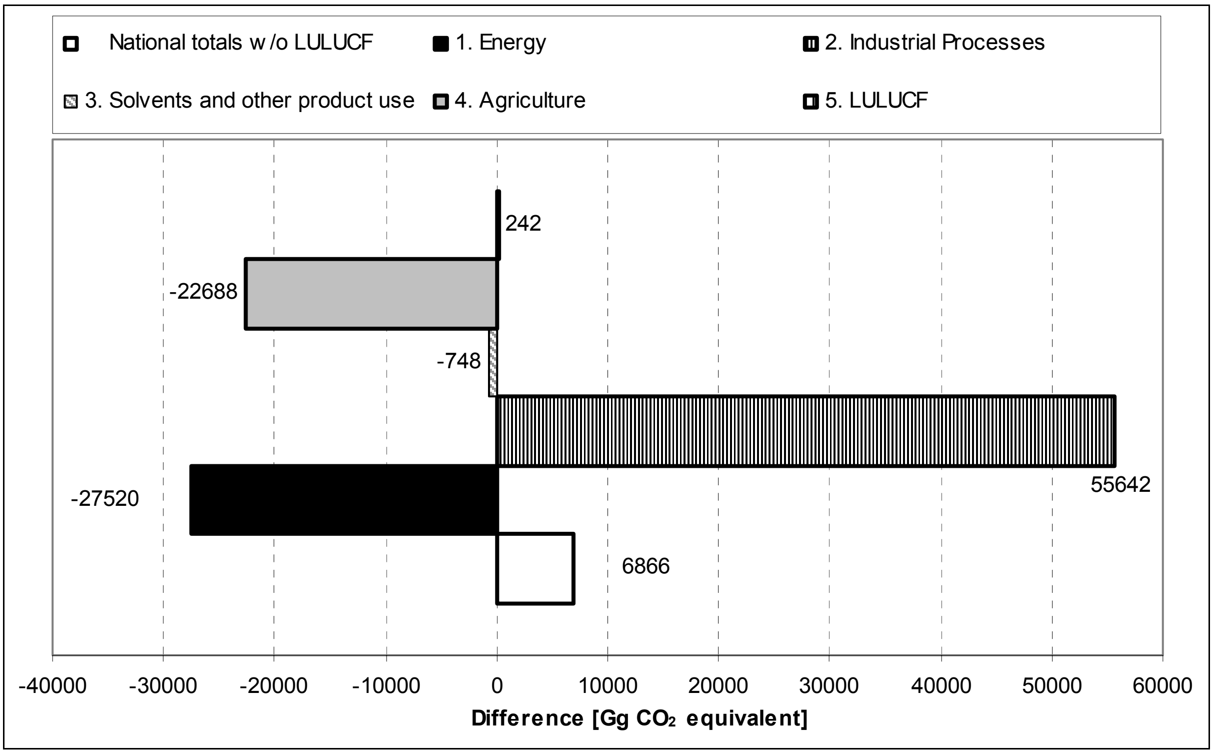


Figure 59: Changes in GG CO_2 equivalent emissions for 1990, with respect to reporting for 2005

10.2.2 Impacts on 2003 emissions levels

In comparison to the 2003 submission, total emissions for 1990, not including LULUCF, changed by – 1.3%.

Emissions recalculations for the agricultural sector, which yielded a result of - 26 %, had the largest impact on total emissions for 2003. Some of the recalculations for the areas of energy and industrial processes were necessitated by emissions transfers. For the first time, the report now includes emissions from secondary fuels. Additional information about recalculations is provided in CRF tables 8(a)s1, 8(a)s2 and 8(b).

Table 106: Recalculation of source-category-specific total emissions, for all gases in 2003

	Change, in CO_2 equivalents [Gg]	Change [%]	Reported 2005 [Gg]	Reported 2006 [Gg]
Total national emissions (not including LUCF)	**6866**	**0,7**	**1017511**	**1024377**
1. Energy	-27520	-3,2	866533	839.012,98
2. Industrial processes	55642	116,7	47686	103.327,39
3. Solvent and other product use	-748	-38,9	1922	1.174,04
4. Agriculture	-22688	-26,0	87328	64.639,70
5. Land-use changes and forestry	242	-0,7	-35690	-35.448,64
6. Waste	2181	15,5	14042	16.223,20

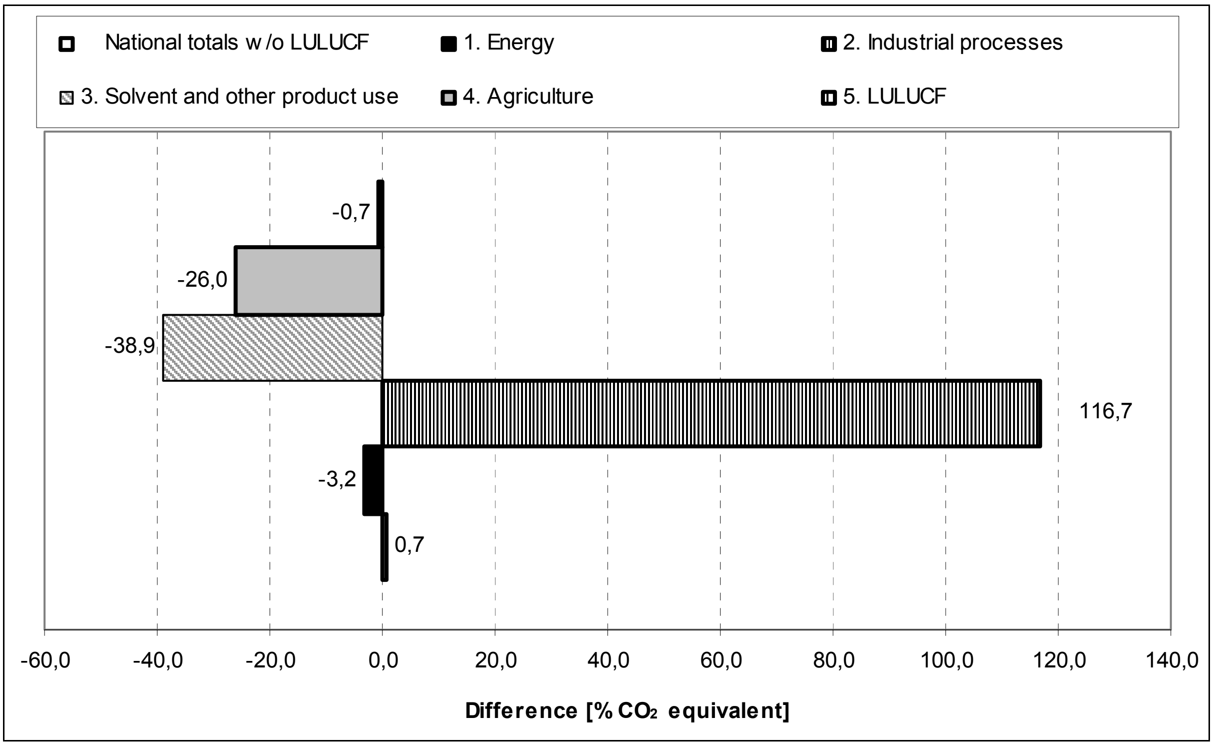


Figure 60: Changes in GG CO_2 equivalents for 2003 (not including LULUCF), with respect to reporting for 2005

10.3 Impacts on emissions trends and on time-series consistency

The time-series consistency has improved as a result of the recalculations.

10.4 Recalculations in response to the review process, and planned inventory improvement

In response to reviews, recalculations were carried out in the following source categories: 1.A.2 and 2.C.

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Anhänge zum Nationalen Inventarbericht

12 ANNEX 1: GERMAN GREENHOUSE GAS INVENTORY KEY CATEGORIES

In accordance with the "*IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*"[71] (*Good Practice Guidance*), the Parties to the Framework Convention on Climate Change, and the Kyoto Protocol, are obliged to calculate and publish annual emissions data.

These emissions inventories must be comprehensible to everyone (transparency), calculated in a comparable manner in the time series since 1990 (consistency), be evaluated uniformly at international level via application of the prescribed calculation methods (comparability), contain all the relevant emission sources and sinks in the reporting country (completeness), and be evaluated with error specification and be subject to permanent internal and external quality management (accuracy).

In order to be able to concentrate the many and detailed activities and capacities required for this purpose on the principal source categories of the inventory, the IPCC has introduced the definition of a "key category". This refers to those source categories which are highlighted in the national inventory system because their emissions have a significant influence on the total emission of direct greenhouse gases, either in terms of absolute emissions, as a contribution to the emissions trend over time, or both.

To this end, the Good Practice Guidance specifies, in chapter 7, the methods to be applied for determining key categories. These methods make it possible, via inventory analysis for one year (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 Trend Assessment with consideration of inaccuracies), to identify the respective key categories.

For the identified key categories, the Parties are then required to use very detailed calculation methods (TIER 2 or higher), which are likewise prescribed in the Good Practice Guidance. Should this prove impossible for a variety of reasons (e.g. data availability for the required input variables, etc.), Parties are required to prove that the methods applied nationally at least achieve a comparable degree of accuracy in the calculation result. These records, as well as the key category analysis performed overall, must be outlined in the national inventory report to be prepared annually.

12.1 Description of the method for determining key categories

The results of the key category analysis based on the two Tier 1 techniques (Level and Trend) are outlined below. We also refer the reader to the description of the underlying methods in the *Good Practice Guidance*. In a departure from that source's proposal for the structure of the relevant source categories, a greater degree of detail was chosen for the present analysis. Annual emissions inventories were divided, in keeping with their CO_2-equivalent emissions, into a total of 177 individual activities.

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71 This Report was produced as a response to a suggestion by the UN Framework Convention on Climate Change to the Intergovernmental Panel on Climate Change (IPCC). The work to determine uncertainties in inventories was to be completed, and a report submitted on "good practice" in inventory management.
Work was carried out with the aim of supporting governments in the preparation of their emissions inventories. The aim was to avoid over-valuation or under-valuation of the results and to reduce the inaccuracies of the inventories as far as possible.
This report is published on the Internet at : http://www.ipcc-nggip.iges.or.jp/public/gp/gpgaum.htm

12.1.1 Tier 1 Level Approach

As a result of this approach, those source categories responsible for 95 % of total national emissions (als CO_2-equivalent emissions), in 1990 and 2004, are identified as key categories (●). Calculations were performed using formula 7.1 from the Good Practice Guidance.

For the source category summary used in this analysis, a total of 34 key categories are identified in 2004 using this approach (cf. Table 107).

Table 107: Key category categories for Germany (1990-2004) based on the Tier 1 Level Approach

IPCC Source Category	Activity	Emissions Of	2004# [Gg CO_2 Equi.]	Level Assessment#	key category#
1A1a Public electricity and Heat production	all fuels	CO_2	317,884.82	30.25	●
1A3b Transport Road Transportation	all fuels	CO_2	160,277.91	15.25	●
1A4b Other Sectors Residential	all fuels	CO_2	115,623.09	11.00	●
1A2f Manufacturing Industries and Construction Other	all fuels	CO_2	94,555.77	9.00	●
1A4a Other Sectors Commercial/Institutional	all fuels	CO_2	46,705.62	4.44	●
2C1 Metal Production Iron and Steel Production	Steel (integrated production)	CO_2	42,490.33	4.04	●
5.B Cropland		CO_2	25,007.14	2.38	●
4D1. Agricultural Soils	Direct Soil Emissions	N_2O	24,626.78	2.34	●
1A1c Manufacture of Solid Fuels and Other Energy Industries	all fuels	CO_2	19,524.02	1.86	●
1A1b Petroleum Refining	all fuels	CO_2	19,490.81	1.85	●
5C Grassland		CO_2	16,598.12	1.58	●
2A1 Mineral Products Cement Production		CO_2	13,929.05	1.33	●
4D3 Agricultural Soils	Indirect Emissions	N_2O	11,822.52	1.13	●
6A1 Managed Waste Disposal on Land		CH_4	11,382.89	1.08	●
4A1 Enteric Fermentation	Dairy Cattle	CH_4	10,038.00	0.96	●
2B5 Chemical Industry	Other	CO_2	9,691.23	0.92	●
2F Industrial Processes	Consumption of Halocarbons and SF_6	HFC´s	8,292.56	0.79	●
2B2 Chemical Industry	Nitric Acid Production	N_2O	7,518.27	0.72	●
4A1 Enteric Fermentation	Non-Dairy Cattle	CH_4	7,112.70	0.68	●
1B2b Fugitive Emissions from Fuels Natural Gas	Natural Gas	CH_4	6,999.20	0.67	●
1A4c Other Sectors Agriculture/Forestry/Fisheries	all fuels	CO_2	6,679.81	0.64	●
1B1a Fugitive Emissions from Fuels Coal Mining and Handling	Solid Fuels	CH_4	6,460.68	0.61	●
1A2a Manufacturing Industries and Construction Iron and Steel	all fuels	CO_2	6,331.08	0.60	●
2A2 Mineral Products Lime Production		CO_2	5,529.36	0.53	●
2B1 Chemical Industry	Ammonia production	CO_2	5,168.91	0.49	●
2B3 Chemical Industry	Adipic Acid Production	N_2O	4,780.87	0.45	

IPCC Source Category	Activity	Emissions Of	2004[#] [Gg CO_2 Equi.]	Level Assessment[#]	key category[#]
1A3a Transport Civil Aviation	Aviation Gasoline	CO_2	4,408.06	0.42	
1A3e Transport Other Transportation	all fuels	CO_2	3,889.97	0.37	
2F Industrial Processes	Consumption of Halocarbons and SF_6	SF_6	2,559.10	0.24	
6B1 Wastewater Handling	Industrial Wastewater	N_2O	2,276.67	0.22	
1A1a Public electricity and Heat production	all fuels	N_2O	1,857.77	0.18	
4B1 Manure Management	Dairy Cattle	CH_4	1,781.71	0.17	
2C4 SF_6 Used in Aluminium and Magnesium Foundries		SF_6	1,682.39	0.16	
1A5 Other Include Military fuel use under this category	all fuels	CO_2	1,656.26	0.16	
4B1 Manure Management	Non-Dairy Cattle	CH_4	1,613.39	0.15	
1A3c Transport Railways	all fuels	CO_2	1,611.06	0.15	
4B8 Manure Management	Swine	CH_4	1,538.92	0.15	
1B1c Fugitive Emissions from Fuels Other (Abandoned Mines)	Solid Fuels	CH_4	1,489.03	0.14	
4D2 Agricultural Soils	Animal Production	N_2O	1,396.95	0.13	
4A2 Enteric Fermentation	other animals	CH_4	1,392.93	0.13	
1A3b Transport Road Transportation	all fuels	N_2O	1,261.82	0.12	
1A2e Manufacturing Industries and Construction Food Processing	all fuels	CO_2	1,032.49	0.10	
3DTotal Solvent and Other Product Use		N_2O	1,007.50	0.10	
4B13 Manure Management Other	Other Cattle	N_2O	961.00	0.09	
1A2b Manufacturing Industries and Construction Non-Ferrous Metals	all fuels	CO_2	936.26	0.09	
2C3 Aluminium Production		CO_2	914.30	0.09	
1A3d Transport Navigation	Diesel Oil	CO_2	867.87	0.08	
1A2f Manufacturing Industries and Construction Other	all fuels	N_2O	697.97	0.07	
2A7 Glass Production		CO_2	680.51	0.06	
6 A3 Other - Composting		CH_4	650.18	0.06	
4D4 Agricultural Soils	Other	CH_4	632.76	0.06	
4B13 Manure Management Other	Dairy Cows	N_2O	620.00	0.06	
4B13 Manure Management Other	Poultry	N_2O	584.97	0.06	
1A4b Other Sectors Residential	all fuels	CH_4	548.47	0.05	
5F Other Land		CO_2	530.82	0.05	
2E Production of Halocarbons and SF_6	production of HCFC-22	HFC´s	511.05	0.05	
2A7 Bricks and Tiles Production	limesto-input	CO_2	475.42	0.05	
2C3 Aluminium Production		PFC´s	445.72	0.04	
4B13 Manure Management Other	Swine	N_2O	387.50	0.04	
2F Industrial Processes	Consumption of Halocarbons and SF_6	PFC´s	384.83	0.04	
1A4b Other Sectors Residential	all fuels	N_2O	364.68	0.03	
4B13 Manure Management Other	other animals	N_2O	287.00	0.03	
4B2 Manure Management	other animals	CH_4	274.60	0.03	

IPCC Source Category	Activity	Emissions Of	2004[#] [Gg CO_2 Equi.]	Level Assessment[#]	key category[#]
1A1c Manufacture of Solid Fuels and Other Energy Industries	all fuels	N_2O	272.17	0.03	
6A3 Other - Composting		N_2O	246.13	0.02	
2E Production of Halocarbons and SF_6	Fugitive emissions	SF_6	239.00	0.02	
1A3b Transport Road Transportation	all fuels	CH_4	199.92	0.02	
1B2a Fugitive Emissions from Fuels Oil	Oil	CH_4	130.16	0.01	
1A4a Other Sectors Commercial/Institutional	all fuels	N_2O	109.47	0.01	
1A2a Manufacturing Industries and Construction Iron and Steel	all fuels	N_2O	108.88	0.01	
1A1a Public electricity and Heat production	all fuels	CH_4	104.91	0.01	
5G Other (please specify)		CO_2	93.13	0.01	
6B1 Wastewater Handling	Industrial Wastewater	CH_4	91.06	0.01	
1A1b Petroleum Refining	all fuels	N_2O	65.70	0.01	
1A3a Transport Civil Aviation	Aviation Gasoline	N_2O	65.09	0.01	
1A4a Other Sectors Commercial/Institutional	all fuels	CH_4	63.64	0.01	
1A2f Manufacturing Industries and Construction Other	all fuels	CH_4	62.63	0.01	
1A2a Manufacturing Industries and Construction Iron and Steel	all fuels	CH_4	53.98	0.01	
1A4c Other Sectors Agriculture/Forestry/Fisheries	all fuels	N_2O	31.53	0.00	
1A4c Other Sectors Agriculture/Forestry/Fisheries	all fuels	CH_4	28.18	0.00	
1A3e Transport Other Transportation	all fuels	N_2O	21.59	0.00	
2B4 Chemical Industry	Carbide Production	CO_2	18.35	0.00	
1A3c Transport Railways	all fuels	N_2O	17.55	0.00	
1A2d Manufacturing Industries and Construction Pulp, Paper and Print	all fuels	CO_2	16.45	0.00	
1A2e Manufacturing Industries and Construction Food Processing	all fuels	N_2O	12.47	0.00	
1A5 Other Include Military fuel use under this category	all fuels	N_2O	11.31	0.00	
1A3d Transport Navigation	Diesel Oil	N_2O	9.45	0.00	
1A1c Manufacture of Solid Fuels and Other Energy Industries	all fuels	CH_4	9.24	0.00	
1B1b Fugitive Emissions from Fuels Solid Fuel Transformation	Solid Fuels	CH_4	8.71	0.00	
1A3e Transport Other Transportation	all fuels	CH_4	8.40	0.00	
1A1b Petroleum Refining	all fuels	CH_4	7.99	0.00	
1A2d Manufacturing Industries and Construction Pulp, Paper and Print	all fuels	N_2O	7.81	0.00	
1A2b Manufacturing Industries and Construction Non-Ferrous Metals	all fuels	N_2O	7.66	0.00	
2B5 Chemical Industry	other	N_2O	5.77	0.00	
1A5 Other Include Military fuel use under this category	all fuels	CH_4	5.14	0.00	
2C2 Ferroalloys Production	Ferroalloys	CO_2	2.20	0.00	
2C1 Metal Production Iron and Steel Production	other	CH_4	1.94	0.00	

IPCC Source Category	Activity	Emissions Of	2004# [Gg CO_2 Equi.]	Level Assessment#	key category#
1A2d Manufacturing Industries and Construction Pulp, Paper and Print	all fuels	CH_4	1.47	0.00	
5 Land-Use Change and Forestry		N_2O	1.36	0.00	
1A3a Transport Civil Aviation	Aviation Gasoline	CH_4	1.18	0.00	
1A2e. Manufacturing Industries and Construction Food Processing	all fuels	CH_4	0.90	0.00	
1A3c Transport Railways	all fuels	CH_4	0.79	0.00	
1A3d Transport Navigation	Diesel Oil	CH_4	0.59	0.00	
1A2b Manufacturing Industries and Construction Non-Ferrous Metals	all fuels	CH_4	0.57	0.00	
2B5 Chemical Industry	other	CH_4	0.21	0.00	
1B2a Fugitive Emissions from Fuels Oil	Oil	CO_2	0.00	0.00	
1B2d Other	Stadtgas	CH_4	0.00	0.00	
2A4 Soda Ash		CO_2	0.00	0.00	
2C5 Other		HFC 134a	0.00	0.00	
2E Production of Halocarbons and SF_6		PFC´s	0.00	0.00	
4G Other	Other	N_2O	0.00	0.00	
1B2c Fugitive Emissions from Fuels Venting and Flaring	Venting and Flaring	CH_4	0.00	0.00	

#) without Sinks

12.1.2 Tier 1 Trend Approach

As a result of this analysis, those source categories which have made a particular contribution to changes in total greenhouse gas emissions in 2004, in terms of the development of their contribution since 1990, are identified as key categories (•). 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 7.2 from the Good Practice Guidance.

For the source category summary used in this analysis, a total of 43 key categories are identified using this approach (cf. Table 108).

Table 108: Key categories for Germany (1990-2004) based on the Tier 1 Trend Approach (without sinks)

IPCC Source Category	Activity	Emissions Of	1990# [CO_2 Equi.]	2004# [CO_2 Equi.]	Trend Assessment#	% Abs.#	Key category #
1A1a Public electricity and Heat production	all fuels	CO_2	330,836.449	317,884.816	0.05113	17.31	•
1A3b Transport Road Transportation	all fuels	CO_2	150,261.538	160,277.912	0.04154	14.07	•
1A1c Manufacture of Solid Fuels and Other Energy Industries	all fuels	CO_2	58,290.188	19,524.015	0.03304	11.19	•
1A2f Manufacturing Industries and Construction Other	all fuels	CO_2	144,359.692	94,555.775	0.02857	9.67	•
6A1 Managed Waste Disposal on Land		CH_4	35,915.115	11,382.887	0.02110	7.14	•
2B3 Chemical Industry	Adipic Acid Production	N_2O	18,804.600	4,780.867	0.01241	4.20	•
1B1a Fugitive Emissions from Fuels Coal Mining and Handling	Solid Fuels	CH_4	18,415.178	6,460.681	0.01010	3.42	•
1A4b Other Sectors Residential	all fuels	CO_2	129,446.041	115,623.088	0.00992	3.36	•
2F Industrial Processes	Consumption of Halocarbons and SF_6	HFC´s	39.780	8,292.562	0.00952	3.22	•
1A5 Other Include Military fuel use under this category	all fuels	CO_2	11,825.988	1,656.264	0.00936	3.17	•
1A4a Other Sectors Commercial/Institutional	all fuels	CO_2	63,949.629	46,705.616	0.00710	2.41	•
2B5 Chemical Industry	Other	CO_2	6,783.105	9,691.233	0.00471	1.59	•
2B2 Chemical Industry	Nitric Acid Production	N_2O	4,673.383	7,518.271	0.00421	1.43	•
1A1b Petroleum Refining	all fuels	CO_2	19,599.901	19,490.810	0.00379	1.28	•
5.B Cropland		CO_2	26,534.197	25,007.138	0.00354	1.20	•
2E Production of Halocarbons and SF_6	production of HCFC-22	HFC´s	4,329.000	511.050	0.00354	1.20	•
1A4c Other Sectors Agriculture/Forestry/Fisheries	all fuels	CO_2	10,917.119	6,679.806	0.00270	0.92	•
1A3a Transport Civil Aviation	Aviation Gasoline	CO_2	2,897.396	4,408.062	0.00232	0.79	•
2C1 Metal Production Iron and Steel Production	Steel (integrated production)	CO_2	49,240.230	42,490.329	0.00205	0.70	•
6B1 Wastewater Handling	Industrial Wastewater	CH_4	2,226.214	91.056	0.00202	0.68	•
1B2b Fugitive Emissions from Fuels Natural Gas	Natural Gas	CH_4	6,383.138	6,999.205	0.00198	0.67	•
2C3 Aluminium Production		PFC´s	2,489.410	445.720	0.00186	0.63	•
2C4 SF_6 Used in Aluminium and Magnesium Foundries		SF_6	188.810	1,682.393	0.00176	0.60	•

IPCC Source Category	Activity	Emissions Of	1990[#] [CO_2 Equi.]	2004[#] [CO_2 Equi.]	Trend Assessment[#]	% Abs.[#]	Key category [#]
2A1 Mineral Products Cement Production		CO_2	15,145.810	13,929.047	0.00162	0.55	•
2B1 Chemical Industry	Ammonia production	CO_2	4,596.386	5,168.911	0.00158	0.53	•
4A1 Enteric Fermentation	Non-Dairy Cattle	CH_4	10,250.100	7,112.700	0.00157	0.53	•
5C Grassland		CO_2	18,555.156	16,598.121	0.00145	0.49	•
1A1a Public electricity and Heat production	all fuels	N_2O	3,646.976	1,857.766	0.00133	0.45	•
4D1 Agricultural Soils	Direct Soil Emissions	N_2O	28,400.940	24,626.779	0.00132	0.45	•
2F Industrial Processes	Consumption of Halocarbons and SF_6	SF_6	4,476.720	2,559.098	0.00132	0.45	•
1A4a Other Sectors Commercial/Institutional	all fuels	CH_4	1,216.099	63.642	0.00109	0.37	•
1A3b Transport Road Transportation	all fuels	CH_4	1,271.088	199.923	0.00098	0.33	•
1A3d Transport Navigation	Diesel Oil	CO_2	2,049.777	867.872	0.00095	0.32	•
1A3c Transport Railways	all fuels	CO_2	2,879.282	1,611.055	0.00089	0.30	
1A3b Transport Road Transportation	all fuels	N_2O	609.316	1,261.824	0.00087	0.30	
1A2e Manufacturing Industries and Construction Food Processing	all fuels	CO_2	1,989.607	1,032.490	0.00071	0.24	
6A3 Other - Composting		CH_4	49.778	650.179	0.00070	0.24	
3DTotal Solvent and Other Product Use		N_2O	1,922.000	1,007.500	0.00067	0.23	
2A2 Mineral Products Lime Production		CO_2	6,136.687	5,529.359	0.00053	0.18	
6B1 Wastewater Handling	Industrial Wastewater	N_2O	2,212.709	2,276.670	0.00052	0.17	
1A4b Other Sectors Residential	all fuels	CH_4	1,200.406	548.466	0.00051	0.17	
4A1 Enteric Fermentation	Dairy Cattle	CH_4	12,663.000	10,038.000	0.00050	0.17	
4B13 Manure Management Other	Dairy Cows	N_2O	1,271.000	620.000	0.00050	0.17	
1A2a Manufacturing Industries and Construction Iron and Steel	all fuels	CO_2	8,171.643	6,331.075	0.00049	0.17	
1A2b Manufacturing Industries and Construction Non-Ferrous Metals	all fuels	CO_2	1,600.467	936.265	0.00045	0.15	
2C2 Ferroalloys Production	Ferroalloys	CO_2	429.000	2.200	0.00041	0.14	
2B4 Chemical Industry	Carbide Production	CO_2	443.160	18.354	0.00040	0.14	
1A3e. Transport Other Transportation	all fuels	CO_2	4,302.258	3,889.969	0.00038	0.13	
2A7. Glass Production		CO_2	1,200.773	680.506	0.00036	0.12	

IPCC Source Category	Activity	Emissions Of	1990# [CO_2 Equi.]	2004# [CO_2 Equi.]	Trend Assessment#	% Abs.#	Key category #
1A4b Other Sectors Residential	all fuels	N_2O	801.899	364.676	0.00034	0.12	
4B1 Manure Management	Non-Dairy Cattle	CH_4	2,310.243	1,613.385	0.00034	0.12	
2F. Industrial Processes	Consumption of Halocarbons and SF_6	PFC´s	138.055	384.826	0.00031	0.11	
1A1c Manufacture of Solid Fuels and Other Energy Industries	all fuels	N_2O	648.748	272.167	0.00030	0.10	
6 A3 Other - Composting		N_2O	14.043	246.135	0.00027	0.09	
1A2f Manufacturing Industries and Construction Other	all fuels	N_2O	1,118.464	697.966	0.00026	0.09	
4B13 Manure Management Other	Other Cattle	N_2O	1,426.000	961.000	0.00025	0.09	
4B1 Manure Management	Dairy Cattle	CH_4	1,906.317	1,781.711	0.00024	0.08	
4B8 Manure Management	Swine	CH_4	1,616.154	1,538.922	0.00023	0.08	
4B13 Manure Management Other	Swine	N_2O	709.900	387.500	0.00023	0.08	
1A5 Other Include Military fuel use under this category	all fuels	CH_4	236.814	5.143	0.00022	0.07	
4B13 Manure Management Other	Poultry	N_2O	516.460	584.970	0.00018	0.06	
4A.2 Enteric Fermentation	other animals	CH_4	1,511.160	1,392.930	0.00017	0.06	
2E Production of Halocarbons and SF_6	Fugitive emissions	SF_6	119.500	239.000	0.00016	0.05	
4B13 Manure Management Other	other animals	N_2O	198.090	286.998	0.00014	0.05	
1A4c Other Sectors Agriculture/Forestry/Fisheries	all fuels	CH_4	176.891	28.175	0.00014	0.05	
1A1b. Petroleum Refining	all fuels	N_2O	199.886	65.699	0.00011	0.04	
5F Other Land		CO_2	530.824	530.824	0.00011	0.04	
2C3 Aluminium Production		CO_2	1,011.923	914.296	0.00009	0.03	
4B2 Manure Management	other animals	CH_4	238.657	274.602	0.00009	0.03	
1A2f Manufacturing Industries and Construction Other	all fuels	CH_4	169.149	62.632	0.00009	0.03	
4D4 Agricultural Soils	Other	CH_4	-672.036	-632.760	0.00009	0.03	
2A7 Bricks and Tiles Production	limesto-input	CO_2	489.818	475.422	0.00008	0.03	
2E Production of Halocarbons and SF_6		PFC´s	80.113	0.000	0.00008	0.03	
1B2a Fugitive Emissions from Fuels Oil	Oil	CH_4	226.636	130.156	0.00007	0.02	
1A3a Transport Civil Aviation	Aviation Gasoline	N_2O	18.207	65.094	0.00006	0.02	

IPCC Source Category	Activity	Emissions Of	1990# [CO_2 Equi.]	2004# [CO_2 Equi.]	Trend Assessment#	% Abs.#	Key category #
4D3 Agricultural Soils	Indirect Emissions	N_2O	14,243.412	11,822.517	0.00005	0.02	
5G Other (please specify)		CO_2	163.570	93.132	0.00005	0.02	
1A5 Other Include Military fuel use under this category	all fuels	N_2O	64.416	11.307	0.00005	0.02	
1A2a Manufacturing Industries and Construction Iron and Steel	all fuels	N_2O	158.145	108.882	0.00003	0.01	
1.B2d. Other	Stadtgas	CH_4	18.970	0.000	0.00002	0.01	
4D2 Agricultural Soils	Animal Production	N_2O	1,706.742	1,396.947	0.00002	0.01	
1A2d Manufacturing Industries and Construction Pulp, Paper and Print	all fuels	CO_2	3.647	16.454	0.00002	0.01	
1A1c Manufacture of Solid Fuels and Other Energy Industries	all fuels	CH_4	26.669	9.244	0.00001	0.00	
1A4a Other Sectors Commercial/Institutional	all fuels	N_2O	144.213	109.467	0.00001	0.00	
1A3d Transport Navigation	Diesel Oil	N_2O	22.334	9.453	0.00001	0.00	
1A2a Manufacturing Industries and Construction Iron and Steel	all fuels	CH_4	54.608	53.984	0.00001	0.00	
1A2b Manufacturing Industries and Construction Non-Ferrous Metals	all fuels	N_2O	19.853	7.665	0.00001	0.00	
1A3c Transport Railways	all fuels	N_2O	31.711	17.547	0.00001	0.00	
1A1a Public electricity and Heat production	all fuels	CH_4	135.070	104.913	0.00001	0.00	
1B1b Fugitive Emissions from Fuels Solid Fuel Transformation	Solid Fuels	CH_4	18.090	8.707	0.00001	0.00	
1A2d Manufacturing Industries and Construction Pulp, Paper and Print	all fuels	N_2O	2.919	7.812	0.00001	0.00	
1B1c Fugitive Emissions from Fuels Other (Abandoned Mines)	Solid Fuels	CH_4	1,806.840	1,489.030	0.00001	0.00	
1A3e Transport Other Transportation	all fuels	N_2O	22.974	21.589	0.00000	0.00	
1A2e Manufacturing Industries and Construction Food Processing	all fuels	CH_4	3.765	0.904	0.00000	0.00	
1A4c Other Sectors Agriculture/Forestry/Fisheries	all fuels	N_2O	40.532	31.525	0.00000	0.00	

IPCC Source Category	Activity	Emissions Of	1990# [CO_2 Equi.]	2004# [CO_2 Equi.]	Trend Assessment#	% Abs.#	Key category #
1A2e Manufacturing Industries and Construction Food Processing	all fuels	N_2O	13.487	12.474	0.00000	0.00	
2C1 Metal Production Iron and Steel Production	other	CH_4	3.919	1.944	0.00000	0.00	
1A3c. Transport Railways	all fuels	CH_4	2.310	0.790	0.00000	0.00	
1A2d Manufacturing Industries and Construction Pulp, Paper and Print	all fuels	CH_4	0.549	1.470	0.00000	0.00	
2B5 Chemical Industry	other	N_2O	5.766	5.766	0.00000	0.00	
1A3d Transport Navigation	Diesel Oil	CH_4	1.674	0.591	0.00000	0.00	
1A3e Transport Other Transportation	all fuels	CH_4	9.368	8.397	0.00000	0.00	
1A3a Transport Civil Aviation	Aviation Gasoline	CH_4	0.822	1.175	0.00000	0.00	
1A2b Manufacturing Industries and Construction Non-Ferrous Metals	all fuels	CH_4	1.164	0.571	0.00000	0.00	
5 Land-Use Change and Forestry		N_2O	1.210	1.360	0.00000	0.00	
1A1b Petroleum Refining	all fuels	CH_4	9.895	7.988	0.00000	0.00	
2B5 Chemical Industry	other	CH_4	0.253	0.214	0.00000	0.00	
1B2a Fugitive Emissions from Fuels Oil	Oil	CO_2	0.001	0.001	0.00000	0.00	
2A4 Soda Ash		CO_2	0.000	0.000	0.00000	0.00	
2C5. Other		HFC 134a	0.000	0.000	0.00000	0.00	
4G Other	Other	N_2O	0.000	0.000	0.00000	0.00	
1B2c Fugitive Emissions from Fuels Venting and Flaring	Venting and Flaring	CH_4	0.000	0.000	0.00000	0.00	

#) without Sinks

12.1.3 Tier 2 Approach

The key-source analysis pursuant to the Tier 2 approach is based on the results of uncertainties determination pursuant to Tier 2. Previously, no uncertainties for the German greenhouse-gas inventory were determined pursuant to the Tier 2 approach, using Monte Carlo simulation. In the previous procedure, experts' estimations of activity rates and emission factors were carried out, for the various source categories and to various extents. These were complemented with data from the literature, to obtain complete data sets for technical programme implementation of the calculations required for the Tier 2 method. In connection with uncertainties determination pursuant to Tier 2, as planned, plans also call for taking uncertainties into account in determination of key Categories. The relevant NIR chapters (1.7 and, in the Annex, Chapter 18) provide information about the current status of uncertainties determination.

12.1.4 Evaluation

The results presented are based on a highly detailed analysis carried out in conformance with regulations. A total of 49 key categories (41 Level 1990; 34 Level 2004; 43 Trend) were identifed for the year 2004 (total for both TIER 1 procedures). These sources cause total CO_2-equivalent emissions of 1,018,864 Gg, which corresponds to a share of 97.1 % of the total emissions for 2004. These source categories are treated as key categories for all greenhouse gases, regardless of which of their components are the determining factors for their classification as key categories.

The result is summarised in Table 109 below.

In subsequent work in the research project on quality assurance of the inventories, it will then be necessary to identify key categories based on the Tier 2 methodology.

Table 109: Key categories for Germany (1990-2004) based on the Tier 1 Level and Trend Approach (without sinks)

IPCC Source Category	Activity	Emissions Of	Level[#] 1990	Level[#] 2004	Trend[#] 2004
1A1a Public electricity and Heat production	all fuels	CH_4			
1A1a Public electricity and Heat production	all fuels	CO_2	•	•	•
1A1a Public electricity and Heat production	all fuels	N_2O			•
1A1b Petroleum Refining	all fuels	CH_4			
1A1b Petroleum Refining	all fuels	CO_2	•	•	•
1A1b Petroleum Refining	all fuels	N_2O			
1A1c Manufacture of Solid Fuels and Other Energy Industries	all fuels	CH_4			
1A1c Manufacture of Solid Fuels and Other Energy Industries	all fuels	CO_2	•	•	•
1A1c Manufacture of Solid Fuels and Other Energy Industries	all fuels	N_2O			
1A2a Manufacturing Industries and Construction Iron and Steel	all fuels	CH_4			
1A2a Manufacturing Industries and Construction Iron and Steel	all fuels	CO_2	•	•	
1A2a Manufacturing Industries and Construction Iron and Steel	all fuels	N_2O			
1A2b Manufacturing Industries and Construction Non-Ferrous Metals	all fuels	CH_4			
1A2b Manufacturing Industries and Construction Non-Ferrous Metals	all fuels	CO_2			
1A2b Manufacturing Industries and Construction Non-Ferrous Metals	all fuels	N_2O			
1A2d Manufacturing Industries and Construction Pulp, Paper and Print	all fuels	CH_4			
1A2d Manufacturing Industries and Construction Pulp, Paper and Print	all fuels	CO_2			
1A2d Manufacturing Industries and Construction Pulp, Paper and Print	all fuels	N_2O			
1A2e Manufacturing Industries and Construction Food Processing	all fuels	CH_4			
1A2e Manufacturing Industries and Construction Food Processing	all fuels	CO_2			
1A2e Manufacturing Industries and Construction Food Processing	all fuels	N_2O			
1A2f Manufacturing Industries and Construction Other	all fuels	CH_4			
1A2f Manufacturing Industries and Construction Other	all fuels	CO_2	•	•	•
1A2f Manufacturing Industries and Construction Other	all fuels	N_2O			
1A3a Transport Civil Aviation	Aviation Gasoline	CH_4			
1A3a Transport Civil Aviation	Aviation Gasoline	CO_2			•
1A3a Transport Civil Aviation	Aviation Gasoline	N_2O			
1A3b Transport Road Transportation	all fuels	CH_4			•
1A3b Transport Road Transportation	all fuels	CO_2	•	•	•
1A3b Transport Road Transportation	all fuels	N_2O			
1A3c Transport Railways	all fuels	CH_4			
1A3c Transport Railways	all fuels	CO_2			
1A3c Transport Railways	all fuels	N_2O			
1A3d Transport Navigation	Diesel Oil	CH_4			
1A3d Transport Navigation	Diesel Oil	CO_2			•

IPCC Source Category	Activity	Emissions Of	Level# 1990	Level# 2004	Trend# 2004
1A3d Transport Navigation	Diesel Oil	N_2O			
1A3e Transport Other Transportation	all fuels	CH_4			
1A3e Transport Other Transportation	all fuels	CO_2			
1A3e Transport Other Transportation	all fuels	N_2O			
1A4a Other Sectors Commercial/Institutional	all fuels	CH_4			•
1A4a Other Sectors Commercial/Institutional	all fuels	CO_2	•	•	•
1A4a Other Sectors Commercial/Institutional	all fuels	N_2O			
1A4b Other Sectors Residential	all fuels	CH_4			
1A4b Other Sectors Residential	all fuels	CO_2	•	•	•
1A4b Other Sectors Residential	all fuels	N_2O			
1A4c Other Sectors Agriculture/Forestry/Fisheries	all fuels	CH_4			
1A4c Other Sectors Agriculture/Forestry/Fisheries	all fuels	CO_2	•	•	•
1A4c Other Sectors Agriculture/Forestry/Fisheries	all fuels	N_2O			
1A5Other Include Military fuel use under this category	all fuels	CH_4			
1A5Other Include Military fuel use under this category	all fuels	CO_2	•		•
1A5 Other Include Military fuel use under this category	all fuels	N_2O			
1B1a Fugitive Emissions from Fuels Coal Mining and Handling	Solid Fuels	CH_4	•	•	•
1B1b Fugitive Emissions from Fuels Solid Fuel Transformation	Solid Fuels	CH_4			
1B1c Fugitive Emissions from Fuels Other (Abandoned Mines)	Solid Fuels	CH_4			
1B2a Fugitive Emissions from Fuels Oil	Oil	CH_4			
1B2a Fugitive Emissions from Fuels Oil	Oil	CO_2			
1B2b Fugitive Emissions from Fuels Natural Gas	Natural Gas	CH_4	•	•	•
1B2c Fugitive Emissions from Fuels Venting and Flaring	Venting and Flaring	CH_4			
1.B2d Other	Stadtgas	CH_4			
2A1 Mineral Products Cement Production		CO_2	•	•	•
2A2 Mineral Products Lime Production		CO_2	•	•	
2A4 Soda Ash		CO_2			
2A7 Bricks and Tiles Production	limesto-input	CO_2			
2A7 Glass Production		CO_2			
2B1 Chemical Industry	Ammonia production	CO_2	•	•	•
2B2 Chemical Industry	Nitric Acid Production	N_2O	•	•	•
2B3 Chemical Industry	Adipic Acid Production	N_2O	•		•
2B4 Chemical Industry	Carbide Production	CO_2			
2B5 Chemical Industry	other	CH_4			
2B5 Chemical Industry	Other	CO_2	•	•	•
2B5 Chemical Industry	other	N_2O			
2C1 Metal Production Iron and Steel Production	other	CH_4			

IPCC Source Category	Activity	Emissions Of	Level# 1990	Level# 2004	Trend# 2004
2C1 Metal Production Iron and Steel Production	Steel (integrated production)	CO_2	•	•	•
2C2 Ferroalloys Production	Ferroalloys	CO_2			
2C3 Aluminium Production		CO_2			
2C3 Aluminium Production		PFC´s			•
2C4 SF_6 Used in Aluminium and Magnesium Foundries		SF_6			•
2C5 Other		HFC 134a			
2E Production of Halocarbons and SF_6	production of HCFC-22	HFC´s			•
2E Production of Halocarbons and SF_6		PFC´s			
2E Production of Halocarbons and SF_6	Fugitive emissions	SF_6			
2F Industrial Processes	Consumption of Halocarbons and SF_6	HFC´s		•	•
2F Industrial Processes	Consumption of Halocarbons and SF_6	PFC´s			
2F Industrial Processes	Consumption of Halocarbons and SF_6	SF_6	•		•
3D Total Solvent and Other Product Use		N_2O			
4A1 Enteric Fermentation	Dairy Cattle	CH_4	•	•	
4A1 Enteric Fermentation	Non-Dairy Cattle	CH_4	•	•	•
4A2 Enteric Fermentation	other animals	CH_4			
4B13 Manure Management Other	Dairy Cows	N_2O			
4B13 Manure Management Other	other animals	N_2O			
4B13 Manure Management Other	Other Cattle	N_2O			
4B13 Manure Management Other	Poultry	N_2O			
4B13 Manure Management Other	Swine	N_2O			
4B1 Manure Management	Dairy Cattle	CH_4			
4B1. Manure Management	Non-Dairy Cattle	CH_4			
4B2 Manure Management	other animals	CH_4			
4B8 Manure Management	Swine	CH_4			
4D1 Agricultural Soils	Direct Soil Emissions	N_2O	•	•	•
4D2 Agricultural Soils	Animal Production	N_2O			
4D3 Agricultural Soils	Indirect Emissions	N_2O	•	•	
4D4 Agricultural Soils	Other	CH_4			
4G Other	Other	N_2O			
5 Land-Use Change and Forestry		N_2O			
5A Forest Land		CO_2			
5B Cropland		CO_2	•	•	•
5C Grassland		CO_2	•	•	•
5F Other Land		CO_2			
5G Other (please specify)		CO_2			
6A1 Managed Waste Disposal on Land		CH_4	•	•	•
6A3 Other - Composting		CH_4			
6A3 Other - Composting		N_2O			
6B1 Wastewater Handling	Industrial Wastewater	CH_4			•
6B1 Wastewater Handling	Industrial Wastewater	N_2O			

#) without Sinks

13 ANNEX 2: DETAILED DISCUSSION OF METHODOLOGY AND DATA FOR ESTIMATING CO_2 EMISSIONS FROM FOSSIL FUEL COMBUSTION

13.1 The Working Group on Energy Balances, and its most important databases

In the Federal Republic of Germany, energy statistics are published by numerous agencies, and these statistics differ in part in terms of their representation, delimitation and aggregation. Against this background, in the early 1970s, associations of the Germany energy industry, along with economic research institutions, formed the Working Group on Energy Balances (AGEB), aimed at evaluating statistics from all areas of the energy industry on the basis of uniform criteria, combining the data into a well-rounded picture, and making these figures available to the general public in the form of energy balances. The energy balances of the Federal Republic of Germany command a pivotal position in the energy data system by virtue of their structure and conclusiveness. They therefore form the basis for determination of energy-related emissions and for development of scenarios and forecasts of the effects of energy policy and environmental policy measures.

The Energy Balance is prepared by the Working Group on Energy Balances (AGEB), whose members include energy industry associations and energy industry research institutes. The members of the Working Group on Energy Balances (AGEB) include (as of: September 2005):

- Six energy industry associations
  Bundesverband der deutschen Gas- and Wasserwirtschaft e.V. (BGW) (Association of the German Gas and Water Industry), Berlin and Brussels,
  Deutscher Braunkohlen-Industrie-Verein e.V. (DEBRIV) (German Lignite Industry Association), Cologne,
  Gesamtverband des deutschen Steinkohlenbergbaus (GVSt) (General Association of the German Hard Coal Industry), Essen,
  Mineralölwirtschaftsverband (MWV) (Association of the German Petroleum Industry), Hamburg,
  Verband der Elektrizitätswirtschaft- VDEW - e.V. (Electricity Industry Association), Berlin,
  Verband der Industriellen Energie- and Kraftwirtschaft e.V. (VIK) (Association of Industrial Energy and Power Producers), Essen, and
- Three economic research institutes
  Deutsches Institut für Wirtschaftsforschung (DIW) (German Institute for Economic Research), Berlin,
  Energiewirtschaftliches Institut an der Universität Köln (EWI) (Institute of Energy Economics at the University of Cologne), Cologne,
  Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI) (Rhine-Westphalian Institute for Economic Research), Essen.

Until 1994, energy balances were prepared by the General Association of the German Hard Coal Industry (GVSt) in Essen.

Since the 1995 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 cooperation with EEFA (Energy Environment Forecast Analysis

GmbH). The Mineralölwirtschaftsverband e.V. petroleum-industry association provides petroleum data, and the other associations respresented in the Working Group of Energy Balances (AGEB) review data relative to "their" fuels. Overall, with due regard for the available data, the energy balances provide a reliable picture of energy production and use in the German economy.

The most important sources are listed in Table 110 As they indicate, official (e.g. Federal Statistical Office) and semi-official (e.g. coal industry statistics) reporting plays a key role in this context. However, these sources do not provide all necessary data. For this reason, association statistics are also used.

In a number of categories, furthermore, experts personally provide relevant data – in categories, for example, such as non-energetic consumption by the chemicals industry.

Table 110: Data sources for the energy balances

All energy resources	**Federal Ministry of Economics and Technology** Electricity Industry Department – Annual statistical reports Gas Industry Department – Annual statistical reports **Federal Statistical Office** Annual figures for the manufacturing industry Fachserie (Specialised series) F Manufacturing Industry - Series 3.1 Production in the manufacturing industry - Series 4.1.1 Employment, revenue and energy supplies of mining and manufacturing companies - Series 6.4 Power generation facilities of mining and manufacturing companies Fachserie (Specialised series) F4 Foreign Trade - Series 2 Foreign trade by types of goods and countries Selected figures on the energy industry **Association of German Power Utilities (VDEW)** VDEW annual statistics VDEW surveys on the use of renewable energy resources Market research results, company data, calculations by the Working Group on Energy Balances (AGEB)
Hard coal and lignite	**Statistics from the Kohlenwirtschaft e.V. (Coal Industry Association)** Coal mining in the energy industry of the Federal Republic of Germany – annual reports Coal industry statistics Sales statistics and other unpublished energy statistics
Petroleum	**Federal Office of Economics and Export Control** Official Petroleum Statistics for the Federal Republic of Germany **Mineralölwirtschaftsverband e.V. (MWV) (Association of the German Petroleum Industry)** Petroleum Statistics – Annual Reports **Wirtschaftsverband Erdöl- and Erdgasgewinnung e.V. (Association of the Petroleum and Natural Gas Extraction Industry)** Annual reports **Federal Ministry for Food, Agriculture and Forestry** Diesel consumption by agriculture
Gases	**Federal Statistical Office, Düsseldorf branch** Iron and Steel Statistics: Fuel, Gas and Electricity Statistics **Wirtschaftsverband Erdöl- and Erdgasgewinnung e.V. (Association of the Petroleum and Natural Gas Extraction Industry)** Annual reports **Bundesverband der deutschen Gas- and Wasserwirtschaft e.V. (BGW) (Association of the German Gas and Water Industry) Gas Statistics – Annual Reports** Gas statistics – annual reports **Statistics from the Kohlenwirtschaft e.V. (Coal Industry Association)** Gas Statistics **Deutscher Verband Flüssiggas e.V. (German Liquid Petroleum Gas Association)** The LPG Market – Annual Reports
Other energy resources	**Arbeitsgemeinschaft Fernwärme e.V. (Working Group on District Heating)** District heating reports
”Non-fuels”	**Mineralölwirtschaftsverband e.V. (MWV) (Association of the German Petroleum Industry)** Verband der Chemischen Industrie e.V. (VCI) (Chemicals Industry Association)

(ZIESING et al, 2003)

13.2 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 (cf. Figure 61). 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***, as 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 transformation of one substance into another – 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 generation 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 differentiated in accordance with 12 different types of plants.

Energy Balance until 1994	Line
Primary energy balance	
Domestic production	1
Imports	2
Removals from stocks	3
Domestic energy production	*4*
Exports	5
Maritime bunkering	6
Additions to stocks	7
Domestic primary energy consumption	*8*
Transformation balance	
Transformation Input	
Coking plants	9
Municipal gas works	10
Hard-coal briquetting plants	11
Lignite briquetting plants	12
Public district heat plants	13
Mine power stations	14
Other industrial thermal power stations	15
Nuclear power stations	16
Hydroelectric power stations	17
Thermal power stations, district heat stations	18
Blast furnaces	19
Refineries	20
Other energy producers	21
Total transformation input	*22*
Transformation Emissions	
Coking plants	23
Municipal gas works	24
Hard-coal briquetting plants	25
Lignite briquetting plants	26
Public district heat plants	27
Mine power stations	28
Other industrial thermal power stations	29
Nuclear power stations	30
Hydroelectric power stations	31
Thermal power stations, district heat stations	32
Blast furnaces	33
Refineries	34
Other energy producers	35
Total transformation emissions	*36*
Consumption in energy production and in transformation sectors	
Hard-coal mines, hard-coal briquetting plants	37
Coking plants	38
Municipal gas works	39
Lignite mines, briquetting plants	40
Power stations	41
Oil and gas production	42
Refineries	43
Other energy producers	44
Total energy consumption in the transformation sector	45
Flaring and line losses, evaluation difference	**46**
Domestic energy supply and transformation balance	**47**
Non-energy-related consumption	**48**
Statistical differences	**49**
Energy consumption (per sector)	
Final energy consumption	50
Other mining	51
Non-metallic minerals	52
Iron and steel	53
Iron and steel foundries (including malleable casting)	54
Drawing shops and cold rolling mills	55
Non-ferrous metal products and casting	56
Chemical industry	57
Pulp and paper	58
Rubber processing	59
Other basic materials and producer's goods	60
Basic materials and producer's goods	51-60
Machine tools	61
Automotive, aircraft and spacecraft	62
Electrical engineering, precision mechanics, optics	63
Ironware, tinware and metalware	64
Other manufacturing of industrial goods	65
Manufacturing of industrial goods	61-65
Glass and fine ceramics	66
Production of plastic products	67
Textiles	68
Other manufacturing of consumables	69
Manufacturing of consumables	66-69
Sugar industry	70
Other food industry	71
Drink industry	72
Food and drink industry	70-72
Other mining and manufacturing, total	73
Railway transport	74
Road transport	75
Air transport	76
Coastal and inland shipping	77
Total transport	*78*
Total households and small consumers	*79*
Military agencies	80

Energy Balance of the Federal Republic of Germany as of 1995	Line
Primary energy balance	
Domestic production	1
Imports	2
Removals from stocks	3
Domestic energy production	4
Exports	5
Maritime bunkering	6
Additions to stocks	7
Domestic primary energy consumption	8
Transformation balance	
Transformation Input	
Coking plants	9
Hard-coal and lignite briquetting plants	10
Public thermal power stations (not including CHP stations)	11
Industrial thermal power stations	12
Nuclear power stations	13
Hydroelectric power stations, windpower and photovoltaic systems	14
Public CHP stations	15
District heat stations	16
Blast furnaces	17
Refineries	18
Other energy producers	19
Total transformation input	*20*
Transformation Emissions	
Coking plants	21
Hard-coal and lignite briquetting plants	22
Public thermal power stations (not including CHP stations)	23
Industrial thermal power stations	24
Nuclear power stations	25
Hydroelectric power stations, windpower and photovoltaic systems	26
Public CHP stations	27
District heat stations	28
Blast furnaces	29
Refineries	30
Other energy producers	31
Total transformation emissions	*32*
Consumption in energy production and in transformation sectors	
Coking plants	33
Hard-coal mines, hard-coal briquetting plants	34
Lignite mines, briquetting plants	35
Power stations	36
Oil and gas production	37
Refineries	38
Other energy producers	39
Total energy consumption in the transformation sector	40
Flaring and line losses	**41**
Domestic energy supply and transformation sector	**42**
Non-energy-related consumption	**43**
Statistical differences	**44**
Energy consumption (per sector)	
Final energy consumption	45
Non-metallic minerals, other mining	46
Food and tobacco	47
Paper	48
Primary chemicals	49
Other chemical industry	50
Rubber and plastic products	51
Glass and ceramics	52
Processing of non-metallic minerals	53
Metal products	54
Non-ferrous metal products and casting	55
Metal processing	56
Machine tools	57
Automotive industry	58
Other industrial sectors	59
Total mining, extraction of non-metallic minerals, manufacturing	*60*
Railway transport	61
Road transport	62
Air transport	63
Coastal and inland shipping	64
Total transport	*65*
Households	66
Commerce, trade, services and other consumers	67
Military agencies	68

Source: AGEB, 2003

Figure 61: Line structure of energy balances until 1994 and as of 1995

Non-energy consumption, as a component of the consumption balance, is shown as a total, without allocation to plant 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).

Figure 61 shows the structure of the production and consumption balances in the energy balances until 1994 and as of 1995.

Energy resource structure in energy balances ...

Through 1994

Category	Energy resource
Hard coal	HC coal
	HC coke
	HC briquettes
	HC raw tar
	HC pitch
	HC other
	Crude benzene
Lignite	L coal
	L briquettes
	L coke
	L dust coal
	Hard lignite
Other solid fuels	Firewood
	Peat
	Sewage sludge
Petroleum	Oil
	Gasoline
	Raw gasoline
	Jet kerosine
	Schw. Flkr. [??]
	Diesel
	Heating oil, light.
	Heating oil, heavy.
	Petrol coke
	Other petroleum products
Gases	LP gas
	Refinery gas
	Coke-oven gas
	Blast-furnace
	Natural gas
	Petroleum gas
	Pit gas
	Landfill gas
Electricity and other energy resources	Electricity
	Hydropower
	Nuclear power
	District heat
	Other energy resources
Total energy resources	Primary energy resources
	Secondary energy resources
	Total

As of 1995

Category	Energy resource
Hard coal	HC coal
	HC briquettes
	HC coke
	Other HC products
Lignite	L coal
	L briquettes
	Other L products
	Hard lignite
Petroleum	Oil
	Gasoline
	Raw gasoline
	Jet kerosine
	Diesel fuel
	Heating oil, light
	Heating oil, heavy
	Petrol coke
	LP gas
	Refinery gas
	Other petroleum products
Gases	Coke-oven and city gas
	Blast-furn. & converter gas
	Natural gas, petroleum gas
	Pit gas
Renewable energies	Hydropower
	Wind and photovol. systems
	Waste and other biomass
	Other renewable energies
Electricity and other energy resources	Electricity
	Nuclear power
	District heat
Total energy resources	Primary energy resources
	Secondary energy resources
	Total

Source: ZIESING et al, 2003

Figure 62: Energy resources in the Energy Balance of the Federal Republic of Germany

The energy flow in the energy balances is depicted for 30 energy resources. These energy resources may 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, firedamp, excluding landfill gas and the aforementioned gases)
- Renewable energy resources (including waste fuels)
- Electrical power and other energy resources

The main group structure (until 1994 and as of 1995) is shown in Figure 62. Via the "Renewable energies" satellite balance, renewable energies can be further broken down as of 1996 (AGEB 2003).

It should be noted that as the energy-resource structure in the area of renewable energies / waste was changed as of 2000: hydroelectric and windpower, along with photovoltaic systems, were combined, and waste/biomass was divided into renewable and non-renewable fractions. Furthermore, the DIW, which is responsible for preparing Energy Balances, reports that as of the 2003 Energy Balance a further change in the energy-resource structure is to be expected. This will not have an consequences for emissions reporting, however, since the reported data for the years 2000-2004 is based on preliminary Energy Balances, prepared by Federal Environmental Agency, with the structure used for 1995-1999 (cf. Chapter 13.4).

In the energy balance, energy resources are first listed with their specific units. The so-called *natural units* used are tonnes (t) for solid and liquid fuels, cubic metres (m³) 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.

13.3 Reallocation of statistical differences into the sector "residential, institutional and commercial"

The AGEB energy balances, for the old German Länder, and the IfE energy balances, for the new German Länder, are being aggregated for the new energy balances prepared in the framework of the EUROSTAT project (ZIESING et al, 2003) for the year 1990, and for Germany as a whole. In keeping with the system used since 1995, the following change, *inter alia*, has been made in the original balances for 1990 and for the years 1991 to 1994:

The statistical differences listed separately for electrical energy in the energy balances for the old German Länder, until 1994, are now assigned retroactively, and more properly, to the residential, institutional and commercial area (new name: commerce, trade, services).

The statistical differences transferred to the residential, institutional and commercial sector (households and small consumers), in the area of electrical energy, consist of the following values, which are added to the sector's consumption:

[GWh]	1990	1991	1992	1993	1994
Allocation of statistical differences in the electric energy sector to the residential, commercial and institutional / commerce, trade and service sector	8658	13848	14748	16522	18682

13.4 Preparation of provisional energy balances onwards from 1999 by the Federal Environmental Agency (UBA)

At present, the final energy balances show a backlog of four years compared with the ”due” balance year (previous year). In order to meet the requirements of up-to-date emissions reporting, the Federal Environmental Agency has prepared provisional energy balances for the years 2000 to 2004 on the basis of detailed evaluation tables by the Working Group on Energy Balances (AGEB). The ***evaluation tables for the Energy Balance*** are prepared annually, in the summer; they contain figures for the relevant previous year. The Working Group on Energy Balances posts them on the Internet. However, it should be noted that the data in the evaluation tables, where not directly derived from the final energy balances for previous years, is of a provisional nature.

The *evaluation tables on the energy balance* contain the following information:

- Structure of energy consumption, by sectors
- Primary energy consumption, by energy resources
- Domestic primary energy production, by energy resources
- Total final energy consumption, by energy resources
- Final energy consumption by the rest of the mining and manufacturing sectors, by energy resources
- Final energy consumption by traffic, by energy resources
- Final energy consumption by households, by energy resources
- Final energy consumption by the trade, commerce and services sector, by energy resources
- Final energy consumption by military agencies, by energy resources
- Use of energy resources for power generation.

The Federal Environmental Agency has supplemented the transformation balance for 1999, thereby producing provisional energy balances for the years 2000 to 2004. It has accomplished this by adding key data, arranged by source categories, on primary energy consumption, fuel input for power generation, the domestic energy supply pursuant to the transformation balance (this consists of primary consumption, minus transformation losses and energy consumption in the transformation sector), non-energy-related consumption and final energy consumption.

13.5 Methodological issues: Energy-related activity rates

Essentially, the inventories for air pollutants and greenhouse gases prepared by the UBA are strictly based on the energy balances for Germany prepared by the Working Group on Energy Balances (AGEB). In some areas, however, the activity rates determined from the energy balance have been supplemented with activity rates from other sources; this is the case, for example, for firewood consumption in the source categories residential, institutional and commercial (trade, commerce, services).

13.5.1 Supplements to the energy balance data

The Energy Balance data has been supplemented with figures from the Federal Statistical Office (DESTATIS, FS19 R1) relative to total inputs of household waste in waste-incineration facilities. The difference between the a) thus-obtained total sum for household-waste inputs in the public electricity and district-heat supply and b) the pertinent Energy Balance data was distributed proportionally to the Energy Balance data (electricity generation in public thermal power stations, heat generation in public thermal power stations and heat generation in public district-heat stations).

A similar procedure is adopted for waste incineration in industrial thermal power plants. In this case, the difference between a) the sum of the Energy Balance data and the data for secondary fuels (obtained by research project FKZ 204 42 203/02) and b) the pertinent waste statistics of the Federal Statistical Office (DESTATIS, FS19 R1) is divided proportionally to the pertinent Energy Balance data (electricity generation in waste-incineration plants of other industrial power stations, and heat production in waste-incineration plants of industrial power stations of the manufacturing and other mining sectors).

The cross-checking of the difference between Energy Balance data and pertinent waste statistics of the Federal Statistical Office is carried out in the described manner only for the old German Länder and for Germany. For the new German Länder, for which the Energy Balance shows higher values than the waste statistics do in both the public and industrial sectors, the Energy Balance data is not adjusted to the level of waste statistics. The reason for this is that in this case the Energy Balance values are more realistic than those of the waste statistics, since the latter tend to underestimate use of industrial waste for energy recovery – which underestimation was also confirmed by the research project "base year and updating" ("Basisjahr und Aktualisierung"), carried out by IE Leipzig (FKZ 20541115). The activity rates for the new German Länder, then, are higher than those given by waste statistics. This procedure is in keeping with the aim of ensuring that no emissions are omitted.

Finally, with regard to the use of waste, combustion in other plants of the transformation sector also deserves mention. From 1993 to 1994, the energy balances for the old *Länder* include data on the use of sewage sludge and waste under "energy consumption in the transformation sector for coke ovens" (line 38 of the energy balance; in the CSE, this input is interpreted as "plastic waste"); from 1995 onwards, the corresponding data for Germany is listed under "consumption in energy production and in the transformation sectors for other energy producers" (line 39 of the energy balance).

The energy balance has also been supplemented (in a second instance) with regard to use of natural gas by compressors in the natural gas network. This is calculated by means of a fixed-rate factor (0.005) that is linked to consumption of natural gas in Germany. The corresponding activity rates until 1994 – for the inventory data analysed in detail to date – are not deducted from the energy consumption data in the transformation sector listed in line 42 or 44 (until 1994). In other words, these are included as additional emissions. For Germany as a whole, in the first half of the 1990s, this produced annual emissions of approximately 700,000 tonnes of CO_2. From 1995 onwards, the use of natural gas for gas compressors is deducted from the energy balance data; however, there is still a need for clarification vis-à-vis the precise procedure (ZIESING et al., 2003).

13.5.2 Reclassification of energy balance data

A series of reclassifications have been carried out as part of the Federal Environmental Agency's preparation of the inventories. The involve reclassification, between various fuels, and transfers of some fuel inputs to other consumption sectors.

The following reclassifications were carried out:

- Until 1994, use of jet kerosene in the commerce, trade and services sector (energy balance line 79) was allocated to petroleum use in small combustion installations. From 1995 onwards, use of jet kerosene in the trade, commerce and services sector (line 74), which now also includes the military, has been allocated, as a whole, to military air traffic. However, this transfer represents an emissions volume of no more than 30,000 tonnes of CO_2. This reclassification will only be implemented in the Central System for Emissions (CSE).
- Jet kerosene in the transport sector is allocated to international air traffic at a fixed rate of 80 %. This allocation is only implemented in the CSE.

In source-category-specific allocation, only a few additional deviations – that cancel each other out in the total sum – are to be expected.

13.6 Uncertainties and time series consistency in the energy balance

In an endeavour to ensure that energy balances are always meaningful, it is necessary to make allowance for changes in the underlying statistics, for changes in the energy sector and for changes in requirements of data users. Such changes were made as early as the 1970s. Partly 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 the past few years (ZIESING et al, 2003). By contrast, the Energy Statistics Act (Energiestatistikgesetz), which entered into force in 2003, is having a positive effect.

Energy balances from the year 1950 on are available for the Federal Republic of Germany in the territorial delimitation prior to 3 October 1990. Moreover, energy balances have been drawn up for the years 1990 to 1994 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 (edition 1993, WZ 93), since 1995 only energy balances for Germany as a whole (in the territorial delimitation of 3 October 1990) have been submitted. Due to its late appearance (November 2005), the most recent Energy Balance, that for 2002, has been taken into account only partly in the present inventory.

13.6.1 The balance year 1990 and the energy balances for 1991 to 1994

The base year 1990 plays a key role in national emissions inventories, and it is especially important as a reference year for agreed emissions-reduction targets under climate protection policy. For Germany, admittedly, this is linked to the problem that the country did not have the same national territorial status throughout the entire year of 1990. Radical changes in the territory of the GDR and the new *Länder*, including profound economic woes and fundamental organisational/structural problems, greatly complicated the process of collecting energy statistics in eastern Germany for 1990. This also had certain repercussions for the old *Länder*, for which the AGEB was still able to prepare and publish balances in the conventional manner (ZIESING et al, 2003).

For the GDR / new German Länder, the Institut für Energetik (IfE) in Leipzig assumed the tasks of preparing an energy balance for 1990 that would be compatible with western German balances and of presenting the pertinent underlying data in detail (IFE, 1991). In this effort, the Institute had access to a study, carried out under the direction of DIW Berlin (German Institute for Economic Research), whose aims included preparing suitable energy balances for the GDR and the years 1970 to 1989 (DIW, 1991).

The AGEB energy balances, for the old German Länder, and the IfE energy balances, for the new German Länder, are being aggregated for the new energy balances prepared in the framework of the EUROSTAT project (ZIESING et al, 2003) for the year 1990, and for Germany as a whole. In keeping with the system in force as of 1995, the changes described in Chapter 13.5.1 have been made in the original balances for 1990 and for the years 1991 to 1994 (cf. ZIESING et al, 2003).

Furthermore, in keeping with the procedure used by international organisations (IEA, EUROSTAT, ECE), the so-called "efficiency approach" is used, instead of the formerly used "substitution approach", for energy balances for Germany since 1995. The complete energy balances have been recalculated, using the efficiency approach, for the period back to 1990, while primary energy consumption, broken down by energy resources, has been recalculated back to 1980.

This approach is used for assessment of energy resources for which there is no standardised measure for conversion (such as calorific value). The categories involved include foreign trade in electricity, hydroelectric and wind power, photovoltaic systems and nuclear power.

Due to a lack of relevant data, it was not possible to adapt the differentiation of final energy consumption by source categories in the manufacturing sector, for which the system changed considerably as of 1995 via transition from the production sector system (SYPRO) to the economic-sector classification system (Klassifikation der Wirtschaftszweige), 1993 edition (DESTATIS, 2002c).

The aforementioned changes have been used to revise the energy balances for Germany, and for the old and new German Länder, for all years from 1990 to 1994.

In the view of DIW Berlin, these energy balances may be considered the standard energy-statistical basis for determining energy-relevant CO_2 emissions in Germany.

In revision of activity rates for stationary combustion in 1990 in the new German Länder, some shifting of fuel inputs between Energy Balance lines resulted. The overall framework remained unchanged, however. This is described in 13.6.1.

Starting with the energy balance for 1995, a further series of adjustments became necessary. These essentially concern methodological changes for the evaluation of energy resources in accordance with standard international procedures, for which there is no uniform conversion yardstick such as calorific value, as well as amendments to individual columns (energy resources) and – due to a new system for the branches of industry in the manufacturing sector (WZ 93) – lines (source categories) in the energy balance matrix. Moreover, from 1995 onwards, energy balances were only submitted for the Federal Republic of Germany as a whole, since the database no longer permits consistently separate representation for the old and new *Länder*. The structures of energy balances until 1994, and as of 1995, are shown in Figure 61 and Figure 62.

13.7 Uncertainties in the activity rates for stationary combustion systems

13.7.1 Method

The uncertainties for the activity rates for stationary combustion systems were estimated by experts, in September and October 2005, of the German Institute for Economic Research (DIW) and the Öko-Institut.

13.7.1.1 Focus of uncertainties estimation

In the main, uncertainties estimation comprises three elements. First of all, the pertinent uncertainty in the Energy Balance was estimated; that uncertainty provides the basis for determination of the activity rates shown in the Balance of Emissions Causes (BEU) as well as those of households and small consumers (residential, commercial and institutional). In addition, the uncertainty tied to the BEU's pertinent data sources and calculation algorithms was assessed. The uncertainty for households and small consumers was estimated independently of the BEU, since the relevant activity rates are not part of the BEU.

The uncertainties for the activity rates were determined for 2004 in the BEU energy units (TJ). The estimates are based mainly on the BEU documentation in the project "Analysis, documentation and revision of the Balance of Emissions Causes" ("Analyse, Dokumentation und Überarbeitung der Bilanz der Emissionsursachen (BEU)") (FKZ 20341 142, UBA 2005). Changes made since then in algorithms and data sources were also taken into account. The uncertainty in the activity rates was estimated on the basis of BEU version 72 (last revision: 09/2005).

The uncertainties were estimated for all of the results tables contained in the BEU. These include Energy Balance lines 11 (Electricity production in public thermal power stations), 12 (Electricity production in industrial thermal power stations), 15 (Heat production in public thermal power stations), 16 (Heat production in district-heat stations), 40 (Heat production in the other transformation sector) and 60 (Heat production in the manufacturing sector).

In addition, the uncertainties were estimated for the 2004 activity data resulting from Energy Balance lines 66 (Households) and 67 (Small consumers / institutional). In a departure from the procedure used for other sectors, this was carried out on the basis of pertinent documents of the Federal Environmental Agency from the year 2002, documents which outline the data sources and calculation algorithms for these two sectors.

13.7.1.2 Procedure for uncertainties estimation

The German Institute for Economic Research (DIW) and the Öko-Institut prepared an assessment scheme for estimating the uncertainties of data sources and calculation algorithms. On this basis, the procedure for estimating uncertainties of activity rates was divided into a total of nine assessment steps:

Assessment of the Energy Balance:

- Natural units: In this step, the uncertainties were estimated that arise in determination of fuel inputs in natural units (t, m^3). Such assessment, for example, focuses on errors in weighing or in measurement of volumes.
- Net calorific values: The net calorific values for pertinent fuels were used to convert fuel inputs given in natural units into inputs referenced to the BEU, in energy units

(TJ). Uncertainties in determination of net calorific values resulted, for example, from differences in the matter states of the different fuels concerned (solid, liquid, gaseous).

- Collection and reporting: This area has to do with uncertainties that can result in collection, reporting and processing of data entered into the Energy Balance. For example, uncertainties can result in that surveys of relevant facilities may be incomplete as a result of delimitation. They can also result from difficulties in determination of annual consumption of some fuels, difficulties owing to potential stockpiling.
- Preliminary status[72]: The final Energy Balance, in its detailed structure, is not yet available; as a result, evaluation is carried out on the basis of the preliminary evaluation tables of the Energy Balance. This is in spite of the fact that such tables list fuels and sectors within a more highly aggregated structure. The preliminary-status error thus results from deviations in figures for consumption of some fuels, in some sectors, occurring between the preliminary evaluation tables and the final Energy Balance.
- In-house energy balance of the Federal Environmental Agency[72]: An internal calculation model of the Federal Environmental Agency is used to determine fuel consumption, in terms of the Energy Balance structure, on the basis of the evaluation tables of the Energy Balance. Uncertainties arise through discrepancies between the in-house energy balance, which is based on numerous assumptions, from the final Energy Balance.
- Other: All other uncertainties.

Assessment of the BEU and of externally determined activity rates (for residential, commercial and institutional):

- Structure and data sources: The BEU breaks down the Energy Balance's fuel inputs into more detailed activity rates, on the basis of additional statistics and assumptions. Uncertainties in so-determined activity rates can arise as a result of the complexity of pertinent calculation algorithms, of implicit or explicit assumptions and of the number and quality of statistics used.
- Projections: Some of the activity rates needed for the BEU cannot be determined up to the current year on the basis of existing algorithms and data sources. In such cases, the activity rates are obtained by projecting activity rates of earlier years. In each case, uncertainties arise from the time lag between the year on which such a projection is based and the report year.
- Other: All other uncertainties.

13.7.1.3 Determination and aggregation of uncertainties

In the main, the uncertainties have been estimated at the level of fuel inputs. Cross-comparisons between different fuels and Energy Balance lines, and between different structural elements and fuels listed in the BEU, ensure that the estimation process is consistent for all activity rates.

[72] For delimitation of the uncertainty from the preliminary nature of figures from uncertainty in the Federal Environmental Agency's own energy balance: The error arising from the figures' preliminary status refers only to the *preliminary nature* of the data that enters into the evaluation tables of the Energy Balance. The error tied to the in-house energy balance refers to the deviation of *divisions* between fuels and Energy Balance lines, in the evaluation tables disaggregated by the in-house energy balance, from the final Energy Balance, under the assumption that the evaluation tables used correspond to the final Energy Balance.

For the Energy Balance, this means that an uncertainties have been estimated for all relevant fuels in the Energy Balance lines under consideration. A total of 8 Energy Balance lines and 27 fuels have been evaluated, in the categories of hard coal, lignite, petroleum / mineral oils, gases and renewable energies. As a result of to 216 uncertainties have to be estimated for each of the aforementioned steps. In actuality, only the fuel inputs included in the BEU have been assessed.

For each activity rate of a fuel j in BEU table *i* of Energy Balance key, the total uncertainty $U_{total,\ i,\ j,\ k}$ thus consists of the uncertainty of the Energy Balance cell relative to the BEU activity rate[73] and of the uncertainty of the BEU itself. To (nearly) every BEU activity rate, the BEU allocates exactly one fuel of an Energy Balance line. Similarly, the uncertainty for a given Energy Balance cell is allocated to a BEU activity rate.

In keeping with the nine possible steps in uncertainties estimation, there up are to nine different uncertainties for each BEU activity rate. These include the following uncertainties:

Energy Balance (EB):

- Natural units (NE): $U_{EB,\ NE,\ j,\ k}$
- Net calorific values (HW): $U_{EB,\ NE,\ j,\ k}$
- Collection and reporting (EM): $U_{EB,\ NE,\ j,\ k}$
- Preliminary nature (VL): $U_{EB,\ VL,\ j,\ k}$
- In-house energy balance of the Federal Environmental Agency (HEB): $U_{EB,\ HEB,\ j,\ k}$
- Other (SO): $U_{EB,\ SO,\ j,\ k}$

BEU

- Structure and data sources (SD): $U_{BEU,\ SD,\ i,\ ,j,\ k}$
- Projection (HR): $U_{BEU,\ HR,\ i,\ j,\ k}$
- Other (SO): $U_{BEU,\ SO,\ i,\ j,\ k}$

In aggregation of these uncertainties, to obtain the total uncertainty, it is assumed that the pertinent partial uncertainties are linked *multiplicatively*. Pursuant to the IPCC Guidelines, the total uncertainty thus is given by the following relationship:

$$U_{total} = \sqrt{U_1^2 + U_2^2 + ... + U_n^2}$$

For the BEU activity rates, the total uncertainty $U_{total,\ i,\ j,\ k}$ is thus defined by the following relationship:

$$U_{total,i,j,k} = \sqrt{U^2_{EB,NE,j,k} + U^2_{EB,HW,j,k} + U^2_{EB,EM,j,k} + U^2_{EB,VL,j,k} + U^2_{EB,HEB,j,k} + U^2_{EB,SO,j,k} + U^2_{BEU,SD,i,j,k} + U^2_{BEU,HR,i,j,k} + U^2_{BEU,SO,i,j,k}}$$

It should be noted that the uncertainties linked to the BEU (such as breakdowns of fuel inputs by various technologies) have impacts only on the uncertainties for emissions of "conventional" air pollutants and not on the uncertainties for CO_2 emissions. The reason is that the pertinent CO_2 emissions depend solely on total fuel inputs and not on the types of technologies involved. For determination of total uncertainties of the greenhouse-gas inventory, in the CSE, the uncertainties for the emission factors and for the activity rates are linked with each other without special correlation – i.e., the uncertainties are considered to be independent of each other. As a result, the above formula would tend to overestimate the uncertainty for CO_2 emissions. For this reason, along with the total uncertainty for each BEU activity rate, the corresponding uncertainty for CO_2 emissions has also been listed. The

[73] An Energy Balance *cell* refers to a fuel within an Energy Balance *line*.

uncertainty of a given BEU activity rate that is relevant with regard to CO_2 emissions is thus reduced to an aggregation of the uncertainties in the Energy Balance:

$$U_{total,i,j,k} = \sqrt{U^2_{EB,NE,j,k} + U^2_{EB,HW,j,k} + U^2_{EB,EM,j,k} + U^2_{EB,VL,j,k} + U^2_{EB,HEB,j,k} + U^2_{EB,SO,j,k}}$$

In spite of the aforementioned overestimation of uncertainties relative to CO_2 emissions that occurs when the total uncertainty inherent in the BEU model is used, the Federal Environmental Agency has decided to enter the relevant higher total uncertainties into the Central System of Emissions. This approach results from use of the precautionary principle – its aim is to ensure that the uncertainties for the activity rates are not underestimated.

The determined total uncertainty for a given activity rate has been limited to no more than +/- 100 %. In cases involving symmetric total uncertainty (example: +/- 10 %), a normal distribution was assumed; in cases involving asymmetric total uncertainty (example: +10 % / -8 %), a log-normal distribution was assumed.

13.7.2 Result

Aggregation of the uncertainties for all nine calculation steps produces the total uncertainty for each BEU activity rate. The smallest calculation total uncertainty was about 6 %, while the largest was 100 %. The total uncertainty thus varies widely between the different activity rates.

A consideration of the maximum determined uncertainties for the various calculation steps shows that the total uncertainty is "dominated" by just a few calculation steps.

For the Energy Balance uncertainties, these include determination of activity rates in natural units, collection and reporting and, in part, the other uncertainties. The various steps can have uncertainties of up to 20 %. In some cases, disaggregation carried out with the help of the Federal Environmental Agency's in-house energy balance also contributes to the uncertainty – with contributions ranging up to 100 %.

With regard to the uncertainties of the BEU, both the disaggregation itself (both structure and data sources) and the projection can involve major uncertainties. No uncertainties occur in cases in which the activity rate is taken directly from the Energy Balance. A high degree of complexity and a lack of transparency generate large uncertainties in disaggregation. At the same time, the estimate shows that new, transparently documented algorithms (Energy Balance lines 11 and 15) can also lead to significant uncertainties when they are based on assumptions. Projection of activity rates can also lead to significant uncertainties. These uncertainties can be expected to decrease, however, since revision of the BEU, along with pertinent implementation in the CSE, should make it possible for calculations to be timely.

Structured analysis of the uncertainty for all activity rates makes it possible to search systematically for potential for improvements in the inventory. The uncertainty of any activity rate should be seen in light of the activity rate's size, in interest of prioritising of any improvement requirements. Table 111 shows that activity rates with a total uncertainty of over 80 % account for a comparatively small share of total fuel inputs for stationary combustion systems – i.e. the very uncertain activity rates will tend to have only minor influence on the quality of the inventory. On the other hand, those activity rates that have a total uncertainty between 30% and 40%, or between 60% and 70%, should receive priority in attempted improvement, since they account for a relatively large share of total fuel inputs.

Table 111: Numbers and sizes of activity rates, along with the pertinent total uncertainties

			Activity Rates	
			Number	**Activity [TJ]**
total			430	8.374.874
No Algorithm / zero activity			188	
0 %	**< Uncertainty ≤**	10 %	17	63.868
10 %		20 %	29	3.011.036
20 %		30 %	18	68.096
30 %		40 %	53	2.126.793
40 %		50 %	17	104.988
50 %		60 %	43	826.681
60 %		70 %	186	2.032.564
70 %		80 %	24	91.443
80 %		90 %	6	11.076
90 %		100 %	35	38.330

Source: Calculations of Öko-Institut

For all activity rates as a whole, the total uncertainties for the various individual activity rates were weighted, with the relevant activities' shares of total activity for all stationary combustion, and then aggregated, in keeping with the IPCC Guidelines, to form a total uncertainty. This yielded total uncertainties of +/- 7 % and of +/- 3 % (for CO_2 emissions). This shows that the in part very high uncertainties for the various activity rates partially cancel each other out in determination of the total uncertainty for all activity rates.

13.8 Documentation of data for the BEU Model

Data documentation is carried out downstream from the BEU-model process (for structure, cf. Table 10 to Table 15). Such documentation is divided into four steps:

- Description of the sector, and provision of a list of literature references
- Compilation of data from the energy balance and from additional sources, with citing of relevant sources
- Data supplementation and evaluation
- Definition of model data

All four work steps are divided in accordance with the source categories within the BEU structure.

In the first step, the relevant sector is described – for example, via provision of production data and the sector's importance within the energy balance. Any special statistical aspects are noted, and origins of the pertinent data are precisely cited.

Data evaluation takes place in the second step (data library). In addition to fuel inputs, data for other source-category-specific, energy-related characteristics (survey aspects) is included in the evaluation. Such data includes, for example, thermal combustion output, emissions, electrical output, power generation and steam generating capacity of power-station boilers. In individual cases, other data is included as well, if it supports conclusions regarding energy input and generation – for example, production data. The data is then prepared in time-series form. On this level, bases for source-specific recalculations are also documented.

In the third step (supplementation and evaluation),

- Uncertainties and time-series consistency are studied, and
- Source-specific quality assurance / control and verification are carried out.

These studies apply to all survey characteristics contained in the data library. The processes of selection of a form for time-series presentation, inclusion of data from various different sources and consideration of other survey characteristics all provide opportunities to check data consistency and quality:

- Time-series presentation makes it possible to identify data items that don't fit within the overall pattern,
- Via comparison of data with similar survey characteristics, but from different sources, sources can be confirmed, rejected or corrected,
- Via addition of data with other survey characteristics, plausibility of unusual data items can be checked (for example, comparison of power generation and fuel input),
- Linking with data with other survey characteristics (such as derivation of efficiencies, determination of fuel inputs from thermal combustion output and their use over time) makes it possible to replace data and close gaps as necessary,
- Enquiries of plant operators can be carried out in order to supplement or correct data,
- Comparison of data with different survey characteristics makes it possible to determine whether data for a certain year, or survey characteristics within a time series (such as older characteristics), always covers the same group of plants (for example, the emissions for a given plant may be listed, but the relevant fuel input is lacking).

These review options cannot be generally formalised. The question of which options can be used depends on the individual case in question and the available data. Any reviews and evaluations are referred to in the documentation.

This evaluation provides the basis for the fourth step, selection of model data. Data for all surveyed characteristics, assessed as sufficiently reliable, is compiled and then combined in the model with data of other source categories / sub-sectors. The data is linked with the energy balance, and the fuel inputs are entered in the BEU model. The BEU model, and the data for other survey characteristics, provide the basis for forecasts and scenarios regarding the impacts of emissions-reduction measures.

To date, documentation has only been carried out for the lignite mining sector. This documentation covers the period 1992 – 2000.

13.8.1 Lignite mining

13.8.1.1 Description of the sector

In 2004, a total of 181.9 Mt of crude lignite were mined in the German lignite mining sector. Lignite mining is carried out in 5 districts (Reviere), with the following production quantities:

Rhineland	100,286	kt
Helmstedt	2,372	kt
Hesse	0	kt
Bavaria	23	kt
Lausatia (Lausitz)	58,996	kt
Central germany (Mitteldeutschland)	20,248	kt

Mining in the district Hesse was discontinued. Of this quantity of mined crude lignite, a total of 167,4 Mt (92%) was converted into electrical power in public thermal power stations.

The lignite mining sector's activities, in addition to mining crude lignite, include producing products from lignite. In 2004, more than 5 Mt of lignite products were produced:

- Lignite briquettes 1.435 Mt
- Dust coal, dry coal and fluidised bed coal 3.634 Mt
- Lignite coke 0.187 Mt

Crude lignite is processed in lignite briquetting plants. Lignite briquetting plants are operated in the Rhineland, Lausatia and central German districts.

In order to meet their own energy demands, briquetting plants operate their own mine power stations. At present, such mine power stations have an electrical output of about 550 MW, and they generate some 2000 GWh of electrical energy. In addition, as combined heat/power generating systems, they generate process steam that is used to dry crude lignite in coal processing.

The briquetting plants in the Lausatia and Mitteldeutschland (central Germany) districts no longer operate their own mine power stations. The remaining briquetting plants obtain electrical power and process steam either from power stations that were integrated within the public grid in 1994 or from new power stations that have come on line (public grid) since 1998. In energy statistics, these power stations are listed as part of the public grid.

In lignite mining, combustion-related emissions occur through operation of:

- Mine power stations, with fuel inputs for generation of electricity and heat
- Other heat generators needed for operation of lignite mines and briquetting plants

The Energy Balance for the Federal Republic of Germany does not have a separate balance line for mine power stations. Until 1994, fuel inputs for electricity generation, by power stations in the hard-coal mining sector, were summarised in line 14, under the heading "Mine and mine-pit power stations" ("Zechen- und Grubenkraftwerke").

Until that year, it was not difficult to separate fuel inputs in line 14 by hard-coal and lignite mining. Since no mine power stations are operated in the new German Länder, line 14 includes only the fuel inputs for mine-pit (Grube) power stations. In the old German Länder, only crude lignite was used in mine-pit power stations, and thus it was possible to assign the remaining fuel inputs to mine (Zeche) power stations.

In early 1995, when the new economic-sector system (WZ 93) was introduced, mine (Zeche and Grube) power stations were combined with other industrial power stations (includes power stations in the sector "Production of non-metallic minerals, other mining and production", power stations of oil refineries and power stations of Deutsche Bahn AG), in line 12 "Industrial thermal power stations". In addition, the new system did not make a distinction between the old and new German Länder.

Mine-pit (Grube) power stations, in contrast to other industrial power stations, have a special position with regard to allocation of fuel inputs for heat generation. As of balance year 1980, in the energy balance this fuel input is no longer allocated to the own consumption of lignite pits and briguetting plants (until 1994, line 40, as of 1995, line 35). Since then, it has been combined with raw-material input, for transformation, of lignite briquetting plants (until 1994, line 12; as of 1995, line 10, "Hard-coal and lignite briquetting plants". Unlike inputs for transformation (crude lignite that is dried and then processed into products), these quantities are burned and produce emissions. For this reason, they must be calculated out of the transformation input.

For it to be possible to continue to identify lignite mining as a source category, and to update its energy data, additional statistics and information have to be evaluated.

The following compilation shows these additional sources, along with the energy balance. The evaluated data has been combined, in the data library, in time-series form. The short-form names of the sources are used.

13.8.1.1.1 Remarks on data sources

GDR Statistics 1989:

The former GDR kept detailed statistics on power stations from 1970 to 1989. These documents were not available to the general public.

These statistics contain information about all of the GDR's power stations, broken down by economic sectors. They include detailed information about equipment (for example, numbers of steam boilers, along with their dates of production and steam generating capacity; numbers and routed outputs of turbines and generators), fuels used and generation of electricity, process heat and district heat.

The 1989 statistics were evaluated for the lignite mining sector, with regard to generator performance and steam generating capacity. Taking into account the dates on which these plants were decommissioned (cf. the source Directive 88/609/EEC), it was possible to extrapolate the above figures, approximately, until 1999 and to use them for sector differentiation and plausibility checks.

DEBRIV, 2003a

In 1993, the Federal Environmental Agency, working from considerations of thermodynamics, derived a procedure for determining use of crude lignite products, in drying of crude lignite, from produced quantities of lignite products. Operators of briquetting plants then used this procedure, on the basis of their specific circumstances (for example, moisture content of crude lignite and products, plants' efficiency coefficients), to determine energy consumption factors. DEBRIV also prepared findings and transmitted the findings with the aforementioned letter.

DEBRIV, 2003b

This source was compiled by the Association of the German lignite industry (Dachverband der deutschen Braunkohlenindustrie - DEBRIV), on the basis of data provided by member companies for the period 1992 to 2001. Along with data on public lignite power stations, this source also provides information about mine-pit (Grube) power stations.

For the new German Länder, and for the aforementioned period, the source provides information on rated electrical output, electricity generation and fuel input in electricity generation. The figures on fuel inputs for heat generation in these plants are incomplete and were not adopted.

The data has been aggregated into two operator groups. In the course of the period in question, the operator groups were repeatedly restructured and renamed. For this reason, the chronological development of survey characteristics for this sector can be derived only by summing over the operator groups.

For the old German Länder, data on mine-pit (Grube) power stations is included only for the years 1998 and 1999.

<u>DEBRIV o. J.</u>

This report series presents the activities of the lignite industry. It contains overviews and tables with figures on lignite production, product production, lignite input in power stations, the stations' electrical output and the stations' expected development. This source can be used to close gaps in data and to confirm some data from other sources.

<u>Jahrbuch Bergbau 1994-2004</u>

Chapter 1.2 "Braunkohle" (Lignite) of this yearbook presents reports of lignite-industry companies, with relevant data. From this data, time series – for example, on power generation of pit power stations in the Rhineland – and quantity data on lignite products, by companies and regions, have been compiled for the data library.

<u>LAUBAG 2002</u>

The LAUBAG letters are the results of a study on mine-pit power stations in the Lausitz district. From these letters, additional information was gleaned, especially information on the old power station "Schwarze Pumpe", that supplemented information from other sources.

<u>RHEINBRAUN</u>

The information consists of an excerpt, prepared by the company, from emissions declarations submitted in the framework of compliance with the German Ordinance on large combustion plants (Großfeuerungsanlagen-Verordnung – 13th. BImSchV). This information complements the information in the source Directive 88/609/EEC.

<u>Directive 88/609/EEC</u>

This is the EU Directive on large combustion plants. This directive requires Member States to provide information, at two-year intervals, on progress in reducing emissions from large combustion plants. Information is requested on thermal output of combustion, as well as on SO_2 and NO_X emissions. The old German Länder have been subject to reporting obligations since 1990, while the new German Länder have been so subject since 1992.

In Germany, Länder immission-control authorities compile data for their areas of responsibility and provide it to the Federal Environmental Agency. The Federal Environmental Agency aggregates the data at the federal level and reports the result to the EU.

Information provided by the Länder in addition to requested information varies greatly in structure. Such information includes details about the operator, the type of plant in question (power station, combustion plant), the relevant economic sector, the location and the fuels used. Because such information varies in structure and comprehensiveness, it is not possible to compile an overview for all of Germany based on such characteristics. For some source categories, such an overview can be prepared through addition of other statistics or through enquiries directed to supervisory authorities and operators. This is the case for the lignite mining sector. The relevant emissions data varies in quality. A distinction must be made between annual data updating on the basis of emissions declarations and annual data updating on the basis of information regarding the relevant previous years. Information of the latter sort can normally be recognised in that its data remains unchanged over certain periods of time.

The Federal Environmental Agency's data compilation for mine-pit (Grube) power stations is oriented, initially, to the former GDR's division of its lignite mining sector into collective combines (Kombinaten); for later periods, the compilation is oriented to the companies that emerged from such combines. The compilation also includes dates of plant decommissioning. Decommissioning dates are used in order to update data, for the entire group of plants in question, with regard to trends for other survey characteristics (such as electrical output).

Federal Statistical Office (DESTATIS, Fachserie 4 Reihe 6.4, 1991-2004)

The Federal Statistical Office also collects energy data within the framework of its official statistics on the manufacturing sector. This data is published, inter alia, in Fachserie (specialised series) 4, Reihe (series) 6.4, power-generation plants of mining and manufacturing companies.

VIK

The Association of the Energy and Power Generation Industry (VIK) has compiled time series from the Federal Statistical Office's annual reports. These time series are incorporated within the data library for the lignite mining sector (electrical output, steam generating capacity, electrical work and fuel input for power generation in the lignite mining sector).

13.8.1.2 Electrical output of mine-pit power stations

For statistical purposes, electrical output is the characteristic value for describing an economic sector's power stations. Formerly, statistics listed gross bottleneck output (Bruttoengpassleistung). Increasingly, plant operators have been recording and reporting their plants' net bottleneck output, and thus statistics include a mixture of both types of figures. This fact hampers statistical comparisons and time-series analysis.

For mine-pit power stations, data of the Federal Statistical Office (old and new German Länder, separate until 1994 and combined for all Germany as of 1995) and data in DEBRIV 2001 has been evaluated. Furthermore, the former GDR's power-station statistics (DDR-Statistik, 1989) for 1989 were included, and extrapolated.

Comparisons with the two other sets of statistics make it possible to delimit the sector and to categorise plants by districts (Reviere).

Such extrapolation was carried out on the basis of the decommissioning dates pursuant to Directive 88/609 EEC and of other information on reassignment of power stations (for example, to the public sector). The resulting extrapolation is presented in the outline of GDR statistics, by collective combines, in Tables II 1.5.4.1 to II 1.5.4.3, and it is summarised in II 1.5.4.4.

In Table II 1.5.1, locations of power stations have been allocated to the Mitteldeutschland (central Germany) and Lausatia districts. Power stations of the former Senftenberg lignite collective combine are allocated to the Lausatia district, while power stations of the former Bitterfeld lignite collective combine are allocated to the Mitteldeutschland district. The Lausatia district, except for the power stations in Espenhain, includes all plants of the former Schwarze Pumpe gas combine.

Table II 1.5.1 shows this reorganisation, and in Table II 1.5.2, these districts are completed through addition of the Rhineland district.

These figures are compared to the aggregated data of the Federal Statistical Office (Table II 1.5.3). In preparation of the Table, an effort was made to determine what locations the Federal Statistical Office did not include and which it included additionally (greyed out until 1994). Direct comparison of the data for the new German Länder is possible only until 1994. The figures yield a good approximation to the data of the Federal Statistical Office.

Table 112: Data availability for various power stations

Power station	Federal Statistical Office (II 1.5.3)	DEBRIV (II 1.5.7)	Federal Environmental Agency (II 1.5.8)
Brieske	Missing value for 1997	Continuous time series, no value for 1997	Continuous time series until 1998
Sonne	Additional value for 1998	Time series until 1996	Time series until 1996
Schwarze Pumpe 1	No values for 1992 and 1997	Continuous time series from 1992 to 1997 (i.e. listed as a mine-mine-pit power station)	Continuous time series from 1992 to 1997
Schwarze Pumpe 3	No data for 1992, 1993, 1995, 1997	Value available only for 1994	Not a mine-pit power station
Schwarze Pumpe 4	No values for 1993-1995, but there is a value for 1996	Value available only for 1994	Not a mine-pit power station
Amsdorf	Data for 1995 and 1997 is lacking	Data for 1995, 1996 and 1997 is lacking	Continuous time series from 1992 to 1999

Direct comparison with the extrapolated data as of 1995 is not possible, since the Federal Statistical Office only provides figures for Germany. Nonetheless, it is possible to determine what locations in the new German Länder were surveyed, or additional included, in the time series for Germany (grey background as of 1995), as well as approximately what data for the Rhineland district the data of the Federal Statistical Office is based on. It must be remembered that the basic statistical data for the Rhineland is known:

- Listed for 1990 to 1994 (old German Länder)
- Data for 2000 and 2001 is identical with the data for Germany (plants in the new German Länder were decommissioned or were no longer classified with the mine-pit power stations)

This basic data indicates that plants in the old German Länder, as a whole, had relatively constant electrical output. This is confirmed in that the gross bottleneck output in the Rhineland district is 386 MW for the entire period (the net output does not remain constant, even in cases in which the plant itself does not change). If, as of 1995, one subtracts the sum for the various locations from the figures for Germany, then a plausible time series results for the Rheinland district (cf. Table II 1.5.3, 2nd line).

The same approach was carried out with the figures in DEBRIV 2001 (Tab. II 1.5.6).

For Table II 1.5.7, an attempt was made to determine what locations DEBRIV does not include, in comparison to our extrapolation (this was not possible for 1994, since DEBRIV lists electrical output incompletely).

From the two comparisons, the conclusions can be drawn, with respect to the original extrapolation pursuant to Table II 1.5.1, that the Schwarze Pumpe 3 and 4 power stations have not been counted among the mine-pit power stations, and that the Amsdorf power station also has not been counted as part of this sector as of 1999.

The extrapolation was modified in keeping with these conclusions (II 1.5.8).

Tab. II 1.5.9 shows trends in electrical output of mine-pit power stations, by districts, in Germany.

13.8.1.3 Power generation (electrical work) in mine-pit power stations

Longer time series for electrical work in mine-pit power stations can be derived from data of

- Federal Statistical Office (DESTATIS)
- DEBRIV, 2003b
- "Bergbau, Energie" ("mining, energy") Yearbook

Time series for the old and new German Länder until 1994, and for Germany as of 1995, can be derived from publications of the Federal Statistical Office.

DEBRIV 2003b reports on the new German Länder from 1992 to 2001, and the "Bergbau und Energie" yearbook fills in all the data gaps for the period 1992 to 2001, for the old German Länder.

Table II 1.6.1 presents the data of the Federal Statistical Office and the time series, based on the yearbook, for the old German Länder. For the comparison period 1992 to 1994, the figures from both sources are identical for the old German Länder (cf. Table 1.6.1.1 and 1.6.6.4). In II 1.6.1, the Federal Statistical Office's time series for the new German Länder was added in the form of a difference to the data for Germany; this was made possible via completion of the time series for the old German Länder, for the period 1995 to 2001.

A comparison of this addition with the data for the new German Länder pursuant to DEBRIV is shown in Table II 1.6.2. Following initial good agreement, the data sets begin to diverge in later periods. The discrepancies are a result of the gaps found in both sources. The two sources can be harmonised well using the individual-plant data in the data library.

For example, the data of the Federal Statistical Office does not include the Amsdorf power stations as of 1996; furthermore, it categorises the Deuben power station inconsistently and in 1998 it does not include the Brieske power station (cf. Table II 1.6.3), while the DEBRIV data does not include the Schwarze Pumpe power station in 1998 (cf. Table II 1.6.4). When such gaps are filled in in both sets of statistics, the statistics agree nearly completely. The resulting agreement has been incorporated within Table II 1.6.5. It shows power generation in the old and new German Länder, and in Germany as a whole, until 2001.

13.8.1.4 Fuel consumption in mine-pit power stations

The following remarks refer to

- Fuel input for power generation
- Fuel input for heat generation (drying of crude lignite)
- Total fuel input

In Germany, mine-pit power stations are operated in the Rhineland (old German Länder), Lausatia (new German Länder) and Central Germany (new German Länder) districts.

An important aspect is to break down fuel inputs in accordance with these districts, since the districts must be differentiated by emission factors, due to variations in their fuel characteristics (e.g. carbon content, sulphur content, water content and net calorific value).

13.8.1.4.1 Fuel consumption for power generation

Data on fuel inputs for power generation are compiled in the data library. The most important sources include:

- AGEB (old and new German Länder), until 1994
- Federal Statistical Office (old and new German Länder until 1994, and Germany as of 1995)
- DEBRIV (new German Länder), until 2001

The first result of these evaluations is shown in Table II 1.7.5, which summarises the relevant comparison and evaluation of the various statistics and literature information.

Specifically:

1) Tab. II 1.7.1 (for the old German Länder) and II 1.7.2 (for the new German Länder) show the comparison between Federal Statistical Office and AGEB data until 1994.
   For the old German Länder, the two sources are identical; for the new German Länder, comparison is possible only for 1994. This comparison shows good agreement.
   For the new German Länder, DEBRIV (pursuant to Table II 1.7.2.5) was included in this comparison (II 1.7.2).
   For 1992 and 1993, the DEBRIV data show minor discrepancies with the Energy Balance; for 1994, they deviate more strongly from the Energy Balance. On the basis of their good agreement with Federal Statistical Office data, and of their completeness, the AGEB data for the period 1992 to 1994 are included in Table II 1.7.5.

2) As of 1995, the Federal Statistical Office data for Germany, pursuant to Table 1.7.1.1, and the results pursuant to DEBRIV (Table II 1.7.2.5), for the new German Länder, are combined.
   The difference between the two data sets is an estimate of the fuel input for the old German Länder (Table 1.7.3). Apart from the years 1998 and 1999, this estimate fits well in the known data for the period 1992 to 1994, and for the period as of 2000, for Germany (since that year: Germany = old German Länder). Since power generation for 1998 and 1999 in these plants (cf. Table II 1.6.5) shows no unusual features, the estimate for these years is rejected and replaced with DEBRIV data (Table II 1.7.1.2). In addition, the last plants still in operation in the new German Länder, in 1998 and 1999, can be identified from data of Federal Statistical Office and DEBRIV (Table II 1.7.4).
   When the DEBRIV data for the old German Länder is added, calculations produce the fuel inputs shown in Table II 1.7.4. Together with figures in Table II 1.7.3 (except for those for 1998 and 1999), the data was included in Table II 1.7.5.

3) Table II 1.7.5 includes a first breakdown of fuel inputs by districts (Reviere). With decommissioning of mine-pit power stations in the Central Germany district in 1996, the data for the new German Länder, as of 1997, is identical with that for the Lausatia district. The time series for the Lausatia district ends with the decommissioning of the last mine-pit power station in 1999.

Tables II 1.7.7 and II 1.7.8 provide a differentiated presentation of the fuel inputs shown in Table II 1.7.5. Until 1994, AGEB figures for lignite were used; as of 1995, the DEBRIV figures for lignite were used.

For other fuels, as of 1995 data of the Federal Statistical Office is used to complete the time series after 1994. It should be noted that the figures for Germany apply to the new German Länder, since only crude lignite was used in the old German Länder.

13.8.1.4.2 Fuel consumption for heat generation (drying of crude lignite)

Table II-1.8.2 shows fuel input for production, in the Rhineland district, of products from crude lignite; it is broken down by products. This table is the result of calculation with the production data in Table I 1.15.6.1 and the specific energy consumption for production (per tonne of these products; Table 1.15.2.1).

Tables II-1.8.3 and II-1.8.4 list the data for the Lausatia and Central Germany districts. As of 1995, an additional breakdown by manufacturers of lignite products is carried out for the Central Germany district. This breakdown is necessary, since the MIBRAG power stations have been part of the public grid since 1995 and their fuel inputs for heat generation must be assigned to the public district heating network. For the firm of ROMONTA, which opreates the Amsdorf power station, production of small quantities of other lignite is only a by-product of mineral-wax production, which requires most of the process steam used by the company.

The specific fuel inputs for mineral-wax production are not known; as a result, they have to be disregarded here.

Statistically, fuel inputs of other operators must be classified as part of briquetting plants' own consumption.

Table II-1.8.1 summarises fuel inputs for lignite drying, by products.

13.8.1.4.3 Fuel consumption for heat and power generation, by districts

Table II 1.7.10 summarises the results to date on lignite input in power stations in the new German Länder. Lignite inputs for heat generation have already been broken down by districts. Such a breakdown remains to be carried out for power generation.

To this end, the following approximation was used:
From the quotient of a) the entire fuel input in the new German Länder and b) the thermal output from combustion in power stations (Table II 1.1.3), the duration of utilisation of the thermal output from combustion is determined. The thermal outputs from combustion, in the Lausatia and Central Germany districts, are multiplied by this duration of utilisation. This approach is based on the assumption that the utilisation duration is the same in both districts. The result, in each case, is the district's total fuel input. The fuel input for heat generation is then deducted from this total fuel input. The difference is the fuel input for power generation, by district.

The fuel input for power generation, as shown in Table II 1.7.8, consists of crude lignite and lignite products. Lignite products have also been broken down by districts.
This is done on the basis of the districts' production data (Table 1.15.6.2 and 1.15.6.3). In Table II 1.6.20, the product shares for the various districts are shown. These quotients are used to break products down by districts (results shown in Tables II 1.7.21 and II 1.7.22). Table II 1.7.23 also includes these results for the Rhineland district.

The other energy resources are not broken down by districts (Table II 1.7.24).

For fuel inputs for heat generation in the Lausatia and Central Germany districts, it is assumed that only crude lignite is used (Tables II 1.7.25 and II 1.7.26). This assumption holds for the Rhineland district (Table II 1.7.27).

Tables II 1.7.29 and II 1.7.30 present the relevant results, broken down by fuel input for electricity and power generation and by districts.

Tables II 1.7.31 through II 1.7.33 present fuel inputs for electricity and heat generation, for purposes of further calculation (emission factors.

13.8.1.4.4 Planned improvements

In drying of lignite, part of each quantity of lignite is burned (emissions-relevant use for energy recovery) in order to dry the other part (substance recycling, no combustion, no CO_2 emissions). Previously, statistics listed the entire mass flow for crude lignite, with the result that the emissions-causing portion of the flow had to be calculated before activity rates – for emissions calculation – could be calculated.

13.8.1.5 Thermal output from combustion, SO_2 and NO_X emissions from mine-pit power stations

In immission-control law, the thermal outputs of combustion plants fired with standard types of fuels are the key criteria used for classifying plants (subject to licensing requirements, not subject to licensing requirements); such thermal outputs are also the key criteria used for defining graduated scales of standards, in legal ordinances and administrative provisions pursuant to the Federal Immission Control Act (BImSchV).

Where data on fuel inputs is lacking or is unreliable, thermal output from combustion, linked with its use over time, is an important figure for determining or estimating fuel inputs and for checking plausibility of fuel-input data.

In energy balance structures, thermal output from combustion is an important structural element for allocating sub-quantities of listed fuel inputs, for delimiting inputs from those of other plants of a given industrial sector and for representing emissions time series. In this light, the thermal output from combustion was used in preparation of the Balance of Emissions Causes (Bilanz der Emissionsursachen - BEU).

In Germany, plants' thermal output from combustion is not recorded in statistics. The data for large combustion plants used here comes from compilations relative to EU Member States' reporting obligations under Directive 88/609/EEC on large combustion plants. This directive requires Member States to provide information, at two-year intervals, on progress in reducing emissions from large combustion plants, and to report such information to the EU. The information obligations include data on thermal output from combustion and on SO_2 and NO_X emissions. For Germany, these obligations have been in force since 1990 (old German Länder) and since 1992 (new German Länder).

In Germany, Länder immission-control authorities compile data for their areas of responsibility and provide it to the Federal Environmental Agency. The Federal Environmental Agency processes the relevant documents and reports the results to the EU.

Information provided by the Länder in addition to requested information varies greatly in structure. Such additional information, which varies in composition and completeness, includes information on the plant operator, the type of plant in question (for example, power stations, district heating plants, industrial combustion plants), the plant's location, the relevant industrial sector and the fuels used. Due to the structural and content differences in such information, it is not possible to use it to prepare a standardised, complete compilation for all of Germany. With additional effort, it is usually possible to classify the plants by sectors.

The relevant emissions data varies in quality. A distinction must be made between annual use of data from plant operators' emissions declarations and updating/extrapolation on the basis of data provided in earlier years. The latter type of data can be recognised in that it exhibits data constancy over certain time periods. The quality of data can be evaluated during further processing (for example, plausibility of emission factors, in terms of their levels and development over time).

The Federal Environmental Agency's data compilation for mine-pit (Grube) power stations in the new German Länder is oriented, initially, to the former GDR's division of its lignite mining sector into collective energy combines (Kombinaten); for later periods, the compilation is oriented to the companies that emerged from such combines. The compilation also contains dates for decommissioning of plants, with the result that other characteristics of the total group of plants in question (such as electrical output) can also be determined.

Table II 1.1.1 provides a compilation, from the data library, relative to thermal output from combustion. Table II 1.1.2 takes account of reallocation of plants into the public grid and of transfers into (regional) districts. For purposes of further calculations relative to fuel inputs, the relevant output percentages are determined for the decommissioning years in question (Table II 1.1.3), and Table II 1.1.4 summarises the decommissioning data.
The relevant SO_2 and NO_X emissions are shown in Tables II 1.2.1 and II 1.2.2 and in Tables II 1.3.1 and II 1.3.2.

13.8.1.6 Compilation of model data (last revision: 31 January 2004)

II-1.5.9 Electrical output of mine-pit power stations in Germany: New definition of districts and corrected extrapolation of the former GDR's statistics (own calculations)

II-1.6.5 Power generation in mine-pit power stations in Germany (own calculation)

II-1.7.29 Fuel input for power generation in mine-pit power stations in Germany (own calculation)

II-1.7.30 Fuel input for heat generation in mine-pit power stations in Germany (own calculation)

II-1.1.5 Thermal output from combustion in mine-pit power stations in Germany (own calculation, last revised 31 December of the relevant year)

II-1.2.1 SO_2 emissions generation in mine-pit power stations in Germany (own calculation)

II-1.2.2 SO_2 emission in mine-pit power stations in Germany, taking reallocations into other source categories into account (own calculation)

II-1.3.1 NO_x emissions generation in mine-pit power stations in Germany (own calculation)

II-1.3.2 NO_x emission in mine-pit power stations in Germany, taking reallocations into other source categories into account (own calculation)

II-1.5.9 Electrical output of mine-pit power stations in Germany: New definition of districts and corrected extrapolation of GDR statistics (own calculations)

		1992	1993	1994	1995	1996	1997	1998	1999	2000
Total	MW	2.434	2.411	2.041	1.767	1.104	1.081	525	410	360
Rheinland (Tab. II-1.5.3)	MW	371	377	358	352	362	386	380	365	360
Lausitz (new definition)	MW	1.278	1.278	1.195	1.166	716	650	100	0	0
Mitteldeutschland (new definition)	MW	785	756	489	249	26	45	45	45	0

Sources:
Table II-1.5.3 (Rheinland) and II-1.5.8 (Lausitz, Mitteldeutschland)
Remark:

II-1.6.5 Power generation in mine-pit power stations in Germany (own calculation)

		1992	1993	1994	1995	1996	1997	1998	1999	2000
Germany	GWh	10.292	9.533	8.888	7.224	5.559	4.361	3.536	2.297	2.063
Old German Länder	GWh	1.958	2.057	2.029	1.947	2.191	2.206	2.126	2.064	2.063
New German Länder	GWh	8.334	7.476	6.859	5.277	3.368	2.155	1.410	233	0

Sources
NGL (1992-2001) pursuant to F. Stat. Office as in Tab. II-1.6.3
OGL (1992-2001) pursuant to F. Stat. Office as in Tab. II-1.6.1

II-1.7.29 Fuel input for power generation in mine-pit power stations in Germany (own calculation)

		1992	1993	1994	1995	1996	1997	1998	1999	2000
Total	TJ	116.163	109.514	96.668	84.253	62.905	47.057	37.414	21.425	17.324
Crude lignite, Rheinland district	TJ	14.590	15.819	15.537	16.645	16.706	17.654	18.570	18.092	17.324
Raw lignite, Lausitz district	TJ	57.489	52.022	37.914	40.497	28.720	23.483	15.890	875	0
Raw lignite, Mitteldeutschland district	TJ	23.529	27.727	27.262	13.030	9.082	4.166	2.955	2.459	0
Lignite briquettes, Lausitz district	TJ	0	0	0	73	36	0	0	0	0
Dry coal and coal dust, Lausitz district	TJ	3.798	3.977	8.955	4.459	1.544	0	0	0	0
Dry coal and coal dust, Mitteldeutschland district	TJ	15.300	8.269	4.914	5.829	952	0	0	0	0
Heavy heating oil, NGL, total	TJ	82	41	41	34	3	3	0	0	0
Coke-oven and city gas, NGL, total	TJ	0	0	0	2.090	2.933	993	0	0	0
Natural gas, NGL, total	TJ	32	32	32	20	1.759	3	0	0	0
Sewage sludge and waste, NGL, total	TJ	1.343	1.627	2.013	1.576	1.170	755	0	0	0

Source:
Tables II-1.7.21, II-1.7.22, II-1.7.23, II-1.7.24
Remark: Lausitz and Mitteldeutschland have been redefined in Table II-1.1.1
Remark: the term "sewage sludge, waste" has been taken from the Energy Balance. In lignite power stations in the new German Länder, this refers to residues from lignite processing: carbonising, gasification, and abrasion in product manufacturing.

II-1.7.30 Fuel input for heat generation in mine-pit power stations in Germany (own calculation)

		1992	1993	1994	1995	1996	1997	1998	1999	2000
insgesamt	TJ	52.425	43.903	31.767	26.009	24.694	20.480	16.452	15.490	12.139
Crude lignite, Rheinland district	TJ	18.175	17.107	15.720	14.817	14.893	14.161	12.526	11.660	12.139
Raw lignite, Lausitz district	TJ	20.231	16.807	12.771	9.485	9.083	6.319	3.926	3.830	0
Raw lignite, Mitteldeutschland district	TJ	14.018	9.989	3.276	1.707	718	0	0	0	0
Lignite briquettes, Lausitz district	TJ									
Dry coal and coal dust, Lausitz district	TJ									
Dry coal and coal dust, Mitteldeutschland district	TJ									
Heavy heating oil, NGL, total	TJ									
Coke-oven and city gas, NGL, total	TJ									
Natural gas, NGL, total	TJ									
Sewage sludge and waste, NGL, total	TJ									

Source:
Tables II-1.7.25, II-1.7.26, II-1.7.27
Remark: Lausitz and Mitteldeutschland have been redefined in Table II-1.1.1
Remark: the term "sewage sludge, waste" has been taken from the Energy Balance. In lignite power stations in the new German Länder, this refers to residues from lignite processing: carbonising, gasification, and abrasion in product manufacturing.

II-1.1.5 Thermal output from combustion of mine-pit power stations in Germany (own calculation, last revision 31 December)

		1992	1993	1994	1995	1996	1997	1998	1999	2000
Total	MW	12.935	12.701	10.777	6.480	4.071	3.642	1.890	1.496	1.496
Lausitz (new definition)	MW									
Mitteldeutschland (new definition)	MW									
Rheinland	MW									

Sources:
Table II-1.1.2 and 1.1.8.2
Remark:
Division of "Schwarz Pumpe" gas combine: Espenhain power station went to Mitteldeutschland district, all other power stations went to Lausitz district
Rheinland assumed to be constant as of 1996

II-1.2.1 SO_2 emissions in mine-pit power stations in Germany (own calculation)

		1992	1993	1994	1995	1996	1997	1998	1999	2000
Total	t/a	359.138	338.421	258.291	177.290	131.606	k.A	k.A	k.A	k.A
Lausitz district (new definition)	t/a									
Mitteldeutschland district (new definition)	t/a									
Rheinland district	t/a									

II-1.2.2 SO_2-Emissions in mine-pit power stations in Germany, taking account of reallocation into other sectors (own calculation)

		1992	1993	1994	1995	1996	1997	1998	1999	2000
Total	t/a	359.138	338.421	231.264	110.628	81.878	33.147	17.840	2.623	0
Lausitz district (new definition)	t/a									
Mitteldeutschland district (new definition)	t/a									
Rheinland district	t/a									

II-1.3.1 NO_X emissions in mine-pit power stations in Germany (own calculation)

		1992	1993	1994	1995	1996	1997	1998	1999	2000
Total	t/a	37.708	33.946	26.729	22.118	16.108	k.A	k.A	k.A	k.A
Lausitz district (new definition)	t/a									
Mitteldeutschland district (new definition)	t/a									
Rheinland district	t/a									

II-1.3.2 NO_X emissions in mine-pit power stations in Germany, taking account of reallocations into other sectors (own calculations)

		1992	1993	1994	1995	1996	1997	1998	1999	2000
Total	t/a	37.708	33.946	25.370	18.452	12.896	k.A	k.A	k.A	k.A
Lausitz district (new definition)	t/a									
Mitteldeutschland district (new definition)	t/a									
Rheinland district	t/a									

[k.A. = no data available]

13.9 CO_2 emission factors

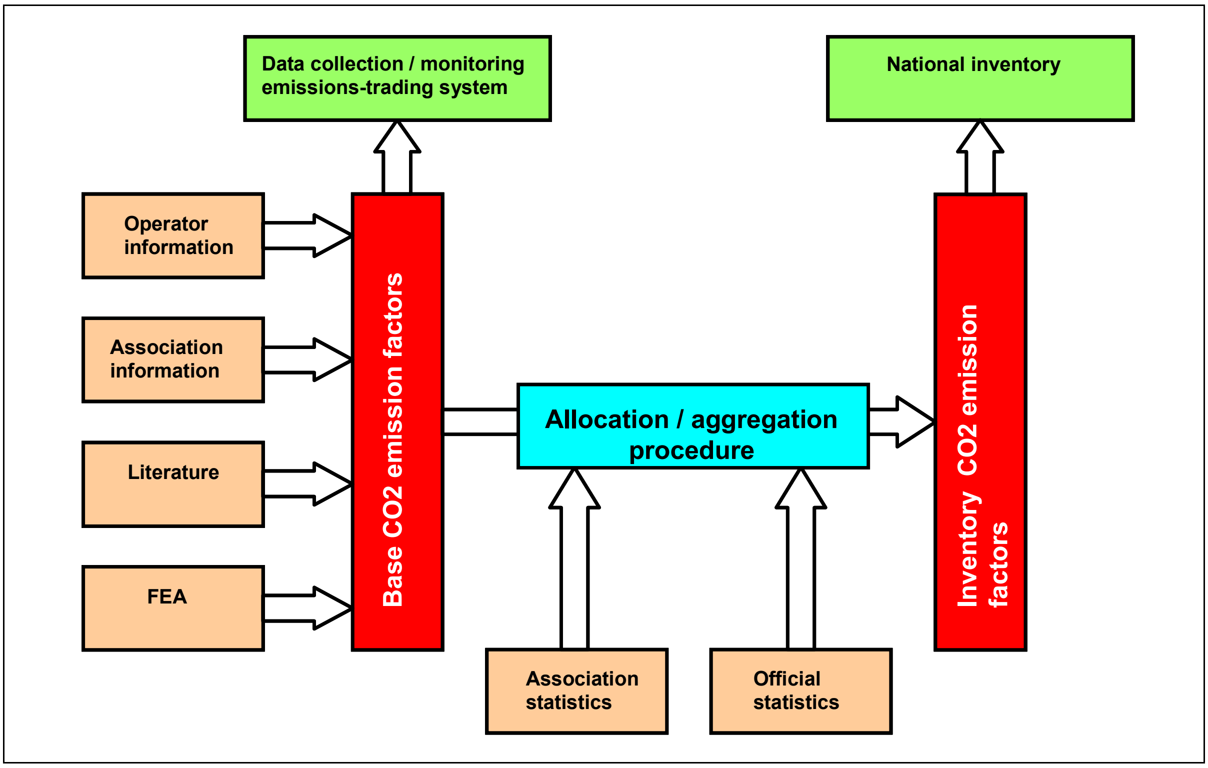
The emission factors on which the inventory is based were derived from the list of *"CO_2 Emissionsfaktoren für die Erstellung der nationalen CO_2-Inventare*" ("*CO_2 Emission factors for preparation of national CO_2 inventories;* ÖKO-INSTITUT, 2004c).

13.9.1 Preliminary remarks on methods

In the framework of data gathering for the National Allocation Plan, the need arose to provide highly differentiated CO_2 emission factors for plant operators, to ensure that determination of plant-specific emissions would be as precise as possible.

At the same time, the CO_2 emission factors for preparation of national inventories are considerably less differentiated, and there is also a need to provide the greatest possible degree of consistency. A high level of consistency between a) the CO_2 emission factors for data collection and monitoring in the framework of the emissions-trading system and b) those used for preparation of national inventories can significantly enhance the quality of inventories and provide a more substantial basis for dealing with inventory-based issues of the National Allocation Plan.

Figure 63: Base and inventory emission factors for CO_2



Source: Öko-Institut

With this in mind, a consistent concept for CO_2 emission factors was developed (In the framework of data gathering for the National Allocation Plan, the need arose to provide highly differentiated CO2 emission factors for plant operators, to ensure that determination of plant-specific emissions would be as precise as possible.

At the same time, the CO2 emission factors for preparation of national inventories are considerably less differentiated, and there is also a need to provide the greatest possible degree of consistency. A high level of consistency between a) the CO2 emission factors for data collection and monitoring in the framework of the emissions-trading system and b) those used for preparation of national inventories can significantly enhance the quality of inventories and provide a more substantial basis for dealing with inventory-based issues of the National Allocation Plan.

Figure 63).

The system is based on a set of differentiated CO_2 emission factors that – for the most part – are geared to the requirements of the emissions-trading system (so-called "base" emission factors for CO_2). These emission factors were developed on the basis of a range of very different data sources. The data includes operator data, data provided by associations and data gained from literature research. Finally, in some cases Federal Environmental Agency data was used, although the origins of such data are not normally specifically documented.

The basic emission factors for CO_2, with the help of structural data from association statistics and (quasi-) official statistics, are allocated and aggregated in such a manner that they can fit with the activity rates that can be used to prepare the national inventories. Emission factors on such an aggregation and allocation level are then referred to as "inventory emission factors" for CO_2.

13.9.2 Base emission factors for CO_2

Up-to-date informations about the base emission factors are available on the intenet site of the Federal Environmental Agency (Umweltbundesamt), following this link:

http://www.umweltbundesamt.de/emissionen/veroeffentlichungen.htm

13.9.3 Determination of inventory emission factors for CO_2

With the basic emission factors for CO_2 (without alternative fuels (Sonderbrennstoffe)), along with data on energy-consumption structures, the CO_2 emission factors were determined at the differentiation level required for national CO_2 inventories (cf. Table 113 and Table 114).

With regard to *hard coal*, it was initially assumed that anthracite is used in small combustion systems, in residential heat-generation systems licensed in accordance with provisions of the Technical Instructions on Air Quality Control (TA Luft), in the small consumption sector (as of 1995: commerce, trade, services) and by military agencies. No further differentiation was carried out for anthracite. Neither was any further differentiation carried out for use of ballast coal.

For mine-pit power stations of the German hard-coal industry, an energy-related mix of German hard-coal production, differented by districts (Ruhr, Saar, Aachen, Lower Saxony) was assumed; data for such a mix is available via the Statistik der Kohlenwirtschaft (coal-industry statistics). The relevant district-specific emission factors were then used, on this basis, to calculate a weighted average.

For other hard-coal uses, a mix of domestic coal and foreign imports, broken down by countries of origin, was determined. The relevant database consisted of the aforementioned domestic-production figures and, initially, detailed data from the Association of Coal Importers (Verein der Kohlenimporteure). For calculation of the import mix, all hard-coal imports, by supplier countries, were adjusted to take account of relevant amounts of coke and coking coal, and of the relevant (small) amounts of imports of other hard-coal products, and then converted to energy content.

The mix for domestic hard-coal production, and that for imports, are linked via the import fraction of hard coal used. This fraction is based on data, provided by the Association of Coal Importers (Verein der Kohlenimporteure), on fractions of imported coal found in the various areas of application. This did not include uses in the iron and steel industry and in coking plants.

The basis for country-specific CO_2 emission factors that enter into the CO_2 emission factor for the import mix consists of (unweighted) averages for the relevant countries of origin. For German hard coal, corresponding production data were used for weighting.

No further differentiation was carried out for hard-coal briquettes and hard-coal coke.

Region-specific data for *raw lignite* was used to obtain aggregated CO_2 emission factors. With data from the Association of the German Lignite Industry (Deutscher Braunkohlen-Industrie-Verein (DEBRIV)), on lignite use in public power stations in the various mining districts (Rhineland, Lausatia, Central Germany, Helmstedt, Hesse, Bavaria), mix values were calculated for the old German Länder, for the new German Länder and for Germany as a whole. In addition, the same database was used to produce a mix for lignite use in public power stations of the Free State of Saxony (Saxony records data on raw lignite production in both the Lausatian and Central German regions).

Through subtraction of amounts of crude lignite used in public power stations, and of amounts used in product production, from total production and import amounts (imports are significant only in connection with use of hard lignite in Bavaria), a difference is obtained that represents crude lignite use. This figure, in turn, can then be broken down by areas of origin.

DEBRIV production data was also used as a basis for calculating weighted averages, for the old and new German Länder and for Germany as a whole, from separate data sets for the various lignite products (lignite briquettes, fluidised-bed coal, pulverised lignite, dry lignite and lignite coke).

No further aggregation was carried out for the CO_2 emission factors for all other fuels; the values referenced in Chapter 13.9.2 were used. The following should be noted with respect to allocations:

- For the period 1990 to 1994, during which separate balances were drawn up for the old and the new German Länder, weighted CO_2 emission factors differentiated according to old and new German Länder were used where appropriate.
- For the period until 1994, the CO_2 emission factor for Russian natural gas was assumed for the new German Länder.
- Gas separated under high pressure from natural gas is only relevant for West Berlin (until 1995).

Finally, it should be noted that, for reasons of consistency, the emission factor for hard-coal coke was used for blast-furnace and converter gas, in preparation of national CO_2 inventories.

Table 113: Aggregation and allocation of basic emission factors for CO_2, 1990-1994

	1990	1991	1992	1993	1994
	t CO_2/TJ				
Steinkohlen					
Steinkohle-Mix	**93,3**	**93,4**	**93,4**	**93,4**	**93,4**
Inländische Produktion	92,9	92,9	92,9	92,9	92,9
Ruhr	93,0	93,0	93,0	93,0	93,0
Saar	92,0	92,0	92,0	92,0	92,0
Aachen	93,0	93,0	93,0	93,0	93,0
Niedersachsen	95,0	95,0	95,0	95,0	95,0
Summe Drittlandsimporte (ohne Koks und Kokskohlen)	95,1	95,0	95,0	94,9	94,9
Polen	94,0	94,0	94,0	94,0	94,0
CSFR	95,0	95,0	95,0	95,0	95,0
UdSSR/GUS	95,0	95,0	95,0	95,0	95,0
Norwegen	94,0	94,0	94,0	94,0	94,0
USA	94,0	94,0	94,0	94,0	94,0
Kanada	95,0	95,0	95,0	95,0	95,0
Kolumbien	94,0	94,0	94,0	94,0	94,0
Südafrika	96,0	96,0	96,0	96,0	96,0
Australien	95,0	95,0	95,0	95,0	95,0
VR China	95,0	95,0	95,0	95,0	95,0
Indonesien	95,0	95,0	95,0	95,0	95,0
Venezuela	93,0	93,0	93,0	93,0	93,0
Sonstige Drittländer	95,0	95,0	95,0	95,0	95,0
Steinkohlenbriketts	93,0	93,0	93,0	93,0	93,0
Steinkohlenkoks	105,0	105,0	105,0	105,0	105,0
Anthrazit					
Stromerzeugung	95,0	95,0	95,0	95,0	95,0
Wärmemarkt	98,0	98,0	98,0	98,0	98,0
Braunkohlen					
Rohbraunkohlen					
(Öffentliche) Kraftwerke	112,1	112,3	112,4	112,5	112,6
(Öffentliche) Kraftwerke (Rheinland, Lausitz, Mitteldeutschlan	112,4	112,7	112,9	112,9	113,0
(Öffentliche) Kraftwerke ABL	113,2	113,2	113,2	113,2	113,3
(Öffentliche) Kraftwerke NBL	111,0	111,2	111,5	111,7	111,7
(Öffentliche) Kraftwerke Sachsen					
Rheinland	114,0	114,0	114,0	114,0	114,0
Helmstedt	111,0	111,0	111,0	111,0	111,0
Hessen	111,0	111,0	111,0	111,0	111,0
Bayern (Hartbraunkohle)	97,0	97,0	97,0	97,0	97,0
Lausitz	113,0	113,0	113,0	113,0	113,0
Mitteldeutschland	104,0	104,0	104,0	104,0	104,0
Restgröße	109,2	109,3	108,2	108,7	109,2
Restgröße ABL	113,9	113,9	113,9	113,9	113,9
Restgröße NBL	108,8	108,7	107,7	108,1	108,6
Rheinland	114,0	114,0	114,0	114,0	114,0
Helmstedt	111,0	111,0	111,0	111,0	111,0
Hessen	111,0	111,0	111,0	111,0	111,0
Bayern	97,0	97,0	97,0	97,0	97,0
Lausitz	113,0	113,0	113,0	113,0	113,0
Mitteldeutschland	104,0	104,0	104,0	104,0	104,0
Braunkohlenbriketts					
Braunkohlenbrikett-Mix Deutschland	99,7	99,9	99,8	99,8	99,9
Braunkohlenbrikett-Mix ABL	99,0	99,0	99,0	99,0	99,0
Braunkohlenbrikett-Mix NBL	99,7	100,0	100,0	100,0	100,3
Rheinland	99,0	99,0	99,0	99,0	99,0
Lausitz	101,0	101,0	101,0	101,0	101,0
Mitteldeutschland	98,0	98,0	98,0	98,0	98,0
Wirbelschicht-, Staub- und Trockenkohle					
Wirbelschicht-, Staub- und Trockenkohle Mix Deutschland	97,6	97,8	97,8	97,9	97,8
Wirbelschicht-, Staub- und Trockenkohle Mix ABL	98,0	98,0	98,0	98,0	98,0
Wirbelschicht-, Staub- und Trockenkohle Mix NBL	96,7	96,6	96,8	97,5	97,1
Rheinland	98,0	98,0	98,0	98,0	98,0
Lausitz	99,0	99,0	99,0	99,0	99,0
Mitteldeutschland	94,0	94,0	94,0	94,0	94,0

Table 113 (con'd)

	1990	1991	1992	1993	1994
	t CO_2/TJ				
Braunkohlen					
Braunkohlenkoks					
Braunkohlenkoks Mix Deutschland	108,0	108,0	108,0	108,0	108,0
Braunkohlenkoks Mix ABL	108,0	108,0	108,0	108,0	108,0
Braunkohlenkoks Mix NBL	108,0	108,0	108,0	108,0	108,0
Rheinland	108,0	108,0	108,0	108,0	108,0
Lausitz	108,0	108,0	108,0	108,0	108,0
Mitteldeutschland	108,0	108,0	108,0	108,0	108,0
Gase					
Kokerei-/Stadtgas	40,0	40,0	40,0	40,0	40,0
Stadtgas NBL	50,0	50,0	50,0	50,0	50,0
Stadtgas West-Berlin (Spaltgas)	53,0	53,0	53,0	53,0	53,0

Table 114 Aggregation and allocation of basic emission factors for CO_2, 1995-2002

	1995	1996	1997	1998	1999	2000	2001	2002
	$t\ CO_2/TJ$							
Steinkohlen								
Steinkohle-Mix	**93,4**	**93,5**	**93,6**	**93,7**	**93,7**	**93,7**	**93,8**	**93,9**
Inländische Produktion	92,9	92,9	92,9	92,9	92,9	92,9	92,9	92,9
Ruhr	93,0	93,0	93,0	93,0	93,0	93,0	93,0	93,0
Saar	92,0	92,0	92,0	92,0	92,0	92,0	92,0	92,0
Aachen	93,0	93,0	93,0	93,0	93,0	93,0	93,0	93,0
Niedersachsen	95,0	95,0	95,0	95,0	95,0	95,0	95,0	95,0
Summe Drittlandsimporte (ohne Koks und Kokskohlen)	94,8	95,0	94,9	94,9	94,8	94,6	94,7	94,8
Polen	94,0	94,0	94,0	94,0	94,0	94,0	94,0	94,0
CSFR	95,0	95,0	95,0	95,0	95,0	95,0	95,0	95,0
UdSSR/GUS	95,0	95,0	95,0	95,0	95,0	95,0	95,0	95,0
Norwegen	94,0	94,0	94,0	94,0	94,0	94,0	94,0	94,0
USA	94,0	94,0	94,0	94,0	94,0	94,0	94,0	94,0
Kanada	95,0	95,0	95,0	95,0	95,0	95,0	95,0	95,0
Kolumbien	94,0	94,0	94,0	94,0	94,0	94,0	94,0	94,0
Südafrika	96,0	96,0	96,0	96,0	96,0	96,0	96,0	96,0
Australien	95,0	95,0	95,0	95,0	95,0	95,0	95,0	95,0
VR China	95,0	95,0	95,0	95,0	95,0	95,0	95,0	95,0
Indonesien	95,0	95,0	95,0	95,0	95,0	95,0	95,0	95,0
Venezuela	93,0	93,0	93,0	93,0	93,0	93,0	93,0	93,0
Sonstige Drittländer	95,0	95,0	95,0	95,0	95,0	95,0	95,0	95,0
Steinkohlenbriketts	93,0	93,0	93,0	93,0	93,0	93,0	93,0	93,0
Steinkohlenkoks	105,0	105,0	105,0	105,0	105,0	105,0	105,0	105,0
Anthrazit								
Stromerzeugung	95,0	95,0	95,0	95,0	95,0	95,0	95,0	95,0
Wärmemarkt	98,0	98,0	98,0	98,0	98,0	98,0	98,0	98,0
Braunkohlen								
Rohbraunkohlen								
(Öffentliche) Kraftwerke	112,5	112,3	112,3	112,2	112,2	112,1	111,9	112,1
(Öffentliche) Kraftwerke (Rheinland, Lausitz, Mitteldeutschlan	112,8	112,6	112,7	112,7	112,6	112,4	112,3	112,3
(Öffentliche) Kraftwerke ABL	113,3	113,3	113,3	113,2	113,2	113,2	113,2	113,6
(Öffentliche) Kraftwerke NBL	111,4	110,8	110,9	110,8	110,9	110,6	110,4	110,4
(Öffentliche) Kraftwerke Sachsen	111,2	110,8	111,0	110,6	108,9	108,9	109,0	109,2
Rheinland	114,0	114,0	114,0	114,0	114,0	114,0	114,0	114,0
Helmstedt	111,0	111,0	111,0	111,0	111,0	111,0	111,0	111,0
Hessen	111,0	111,0	111,0	111,0	111,0	111,0	111,0	111,0
Bayern (Hartbraunkohle)	97,0	97,0	97,0	97,0	97,0	97,0	97,0	97,0
Lausitz	113,0	113,0	113,0	113,0	113,0	113,0	113,0	113,0
Mitteldeutschland	104,0	104,0	104,0	104,0	104,0	104,0	104,0	104,0
Restgröße	109,8	112,2	113,1	113,1	111,9	112,5	112,0	112,1
Restgröße ABL	113,9	114,0	113,9	114,0	113,9	114,0	114,0	113,7
Restgröße NBL	108,8	111,2	112,2	110,9	106,1	104,0	104,0	104,0
Rheinland	114,0	114,0	114,0	114,0	114,0	114,0	114,0	114,0
Helmstedt	111,0	111,0	111,0	111,0	111,0	111,0	111,0	111,0
Hessen	111,0	111,0	111,0	111,0	111,0	111,0	111,0	111,0
Bayern	97,0	97,0	97,0	97,0	97,0	97,0	97,0	97,0
Lausitz	113,0	113,0	113,0	113,0	113,0	113,0	113,0	113,0
Mitteldeutschland	104,0	104,0	104,0	104,0	104,0	104,0	104,0	104,0
Braunkohlenbriketts								
Braunkohlenbrikett-Mix Deutschland	100,0	100,0	99,9	99,7	99,7	99,7	99,7	99,7
Braunkohlenbrikett-Mix ABL	99,0	99,0	99,0	99,0	99,0	99,0	99,0	99,0
Braunkohlenbrikett-Mix NBL	100,4	100,5	100,5	100,6	100,6	100,6	100,7	100,7
Rheinland	99,0	99,0	99,0	99,0	99,0	99,0	99,0	99,0
Lausitz	101,0	101,0	101,0	101,0	101,0	101,0	101,0	101,0
Mitteldeutschland	98,0	98,0	98,0	98,0	98,0	98,0	98,0	98,0
Wirbelschicht-, Staub- und Trockenkohle								
Wirbelschicht-, Staub- und Trockenkohle Mix Deutschland	97,8	97,7	97,7	97,8	97,9	98,0	98,0	97,9
Wirbelschicht-, Staub- und Trockenkohle Mix ABL	98,0	98,0	98,0	98,0	98,0	98,0	98,0	98,0
Wirbelschicht-, Staub- und Trockenkohle Mix NBL	97,0	96,7	96,6	97,2	97,7	97,9	98,1	97,8
Rheinland	98,0	98,0	98,0	98,0	98,0	98,0	98,0	98,0
Lausitz	99,0	99,0	99,0	99,0	99,0	99,0	99,0	99,0
Mitteldeutschland	94,0	94,0	94,0	94,0	94,0	94,0	94,0	94,0

Table 114 (con'd)

	1995	1996	1997	1998	1999	2000	2001	2002
	t CO_2/TJ							
Braunkohlen								
Braunkohlenkoks								
Braunkohlenkoks Mix Deutschland	108,0	108,0	108,0	108,0	108,0	108,0	108,0	108,0
Braunkohlenkoks Mix ABL	108,0	108,0	108,0	108,0	108,0	108,0	108,0	108,0
Braunkohlenkoks Mix NBL	108,0	108,0	108,0	108,0	108,0	108,0	108,0	108,0
Rheinland	108,0	108,0	108,0	108,0	108,0	108,0	108,0	108,0
Lausitz	108,0	108,0	108,0	108,0	108,0	108,0	108,0	108,0
Mitteldeutschland	108,0	108,0	108,0	108,0	108,0	108,0	108,0	108,0
Gase								
Kokerei-/Stadtgas	40,0	40,0	40,0	40,0	40,0	40,0	40,0	40,0
Stadtgas NBL	50,0	50,0	50,0	50,0	50,0	50,0	50,0	50,0
Stadtgas West-Berlin (Spaltgas)	53,0	53,0	53,0	53,0	53,0	53,0	53,0	53,0

13.10 Development of a preliminary reference approach on the basis of the evaluation tables for the Energy Balance

13.10.1 Background

The energy balances prepared in Germany by the "Working Group on Energy Balances" ("Arbeitsgemeinschaft Energiebilanzen", a private association working under the direction of the German Institute for Economic Research (DIW), are thus far available only up to the year 1999[74]. In the past, this time lag between current reporting requirements and the availability of the pertinent required statistical basis has meant that the so-called "Reference Approach" for determination of national CO_2 emissions within the framework of the national greenhouse-gas inventory could not be carried out on time.

While the Working Group on Energy Balances has already taken action aimed at reducing the time lags for future balances, such action is expected to yield no results before the end of 2005.

In response to this difficulty, the Wuppertal Institute has developed and tested a simple procedure for predicting the Reference Approach results from preliminary evaluation tables for the Energy Balance (which tables are always available quite promptly). This procedure, and its usefulness for prediction, are briefly described in the following section.

13.10.2 Calculation for the preliminary Reference Approach

At present, complete Energy Balances are being submitted with time lags of several years relative to current reporting obligations under the Framework Convention on Climate and the pertinent EU monitoring mechanism. As a result, the Energy Balance evaluation tables, which are subject to much smaller time lags (normally, about 9 months after the end of the relevant balance year), are to be used as an alternative database for carrying out the Reference Approach for balancing combustion-related CO_2 emissions.

The following briefly describes the methods used to this end. To begin with, the figures from the main table, 1.A(b), are compiled. In the area of petroleum products, the tables show some unavoidable gaps on the Balance's production side. Nonetheless, the figures for total domestic consumption (apparent consumption), which are of key importance, are nearly completely available. What is more, to a large extent they can be obtained from the evaluation tables with the necessary level of orderly detail.

[74] Following the completion of the present paper, the energy balances for the years 2000 and 2001 were completed.

1. For the area of **liquid fuels**, the evaluation tables still contain no figures relative to import and export balances. They also do not show the changes in stocks that would be needed for the first 5 columns of table 1.A(b) (Production, imports, exports, international bunkers, stock change). Bunkering of kerosene is estimated, however – in a manner similar to the existing procedure under the Reference Approach – from the kerosene inputs for air transports as shown in Table 2.9 (Transport)[75].

   The figures for the central column, "Apparent consumption", can also be obtained from the evaluation tables:

   f) Inputs of liquid secondary fuels (petroleum products) can be taken from the balance of final-energy inputs, broken down by fuels (Table 2.5), and from the balance of energy inputs in the transport sector (Table 2.9). In the process, the breakdown by fuel categories shown in Table 1.A(b) can largely be adhered to. Inputs of LPG – which are quantitatively insignificant – have to be estimated on the basis of the relevant values for the previous year.

   g) Inputs of crude oil result from the figures for petroleum consumption, as given in the primary-energy consumption balance (Table 2.3), and the figures for petroleum-product consumption as determined via the aforementioned procedure.

2. The balance of **solid fuels** can be obtained nearly completely from the evaluation tables:

   a) For lignite, the produced quantity (Table 2.2.1) and the primary-energy consumption (Table 2.3) are given. The difference is then the net change in stocks, since imports and exports may be considered negligible. The evaluation tables do not provide a basis for preparing a balance of lignite products, i.e. of an imports balance and of changes in stocks. In the first half of the 1990s, this aspect was a relevant source of error; since then, inputs have declined to such an extent, however, that these figures no longer play an significant role.

   b) A similar procedure can be used to prepare a balance for hard coal. In this area, the difference between production (Table 2.2.1) and primary-energy consumption (2.3) is considered to be the import balance. Stock changes and bunkers are ignored. Exports – which are at very low levels – are estimated as a constant share of domestic production.
   Inputs of gas from coking ovens and coking plants, as well as inputs of coking coal, are taken from the final energy balance (Table 2.5). In the process, all "produced gases" (difference between the gas-input and natural-gas-input figures shown in Table 2.5) are included in balancing. The remaining primary energy input is then entered into the balance as inputs of subbituminous coal[76].

3. The balance of **gaseous fuels** is shown in Tables 2.2.1 (primary-energy production) and 2.3 (primary-energy consumption). This difference is treated as an import. Stock changes and exports are considered to be negligible.

By contrast, for **non-energy-related fuel use**, which is shown in Table 1.A.(d), only approximations can be gained from the evaluation tables for the Energy Balance. Only the sum of "non-energy-related consumption" is known, from Table 2.1 of the evaluation tables.

[75] To this end, a lump sum of 80% of kerosene inputs is allocated to international air transports.

[76] As a result, effectively larger quantities of coking coal, coke and gases are entered than would actually be entered under the final reference approach. On the other hand, this procedure partially corrects the imprecision in the total sum of primary energy inputs with hard coal that results via a combination of different products.

The factors and fractions for the year 1999 are used, in unchanged form, for purposes of breaking down the non-energy-related consumption by individual substances, the relevant emission factors and the carbon fractions that are assumed to be permanently stored in products relative to the individual substances in question. While this method is rather general, the pertinent fractions for the various products fluctuate only slightly over time. In addition, the emission factors usually differ only slightly from product to product, and thus the potential error, with respect to total emissions, remains within narrow boundaries.

13.10.3 Assessment of the predictive accuracy of the procedure developed

A number of principal error sources arise in use of the simplified reference approach. The most important of these include:

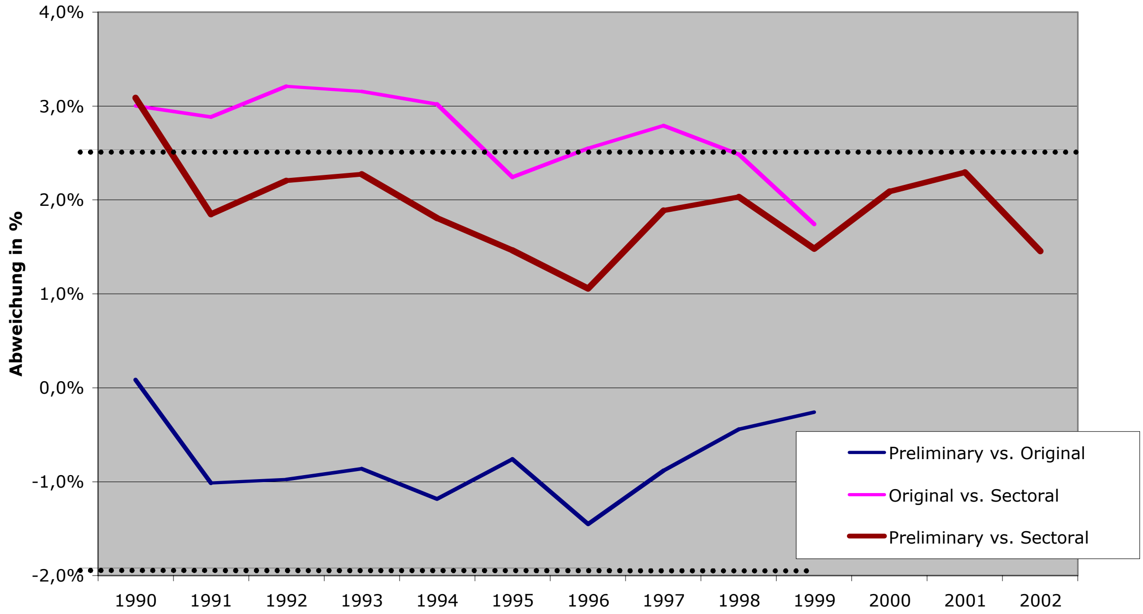
- The error resulting from continued use of the same emission factors for fuels,
- The error resulting from division of non-energy-related consumption among products, in keeping with an older structure,
- The error resulting in that only preliminary evaluation tables are available for the years between the reporting year and the current year; such tables are usually corrected when the the next version of the evaluation tables or the final balance becomes available.
- All three error sources were systematically analysed:
- To make it possible to assess the first two error sources in terms of their significance, the structure of the reference approach for 1999 (the last available year), along with the method developed here, were used, on the basis of the evaluation tables for the Energy Balance, to calculate the reference approach tables for all years from 1990 to 1998.

  The results so obtained from the evaluation tables, with the above-described method, were compared with the "official" reference approach, carried out with the complete Energy Balance, to determine the order of the magnitude of the procedure selected here. The results are differentiated by absolute error, with regard to the deviation of the total results for energy inputs and CO_2 emissions, and to trend-prediction precision, i.e. to how precisely the "preliminary reference approach", in comparison to the final reference approach, determines the rate of change from the previous year.

  In addition, the results were compared to those from the more detailed sectoral approach – which, for systematic reasons, also departs from the reference approach.
- The error resulting from corrections in the preliminary evaluation tables for the Energy Balance is described only by way of example, in terms of the changes, made between the evaluation tables of 2004 and those of 2005, for the 2002 and 2003 balance years.

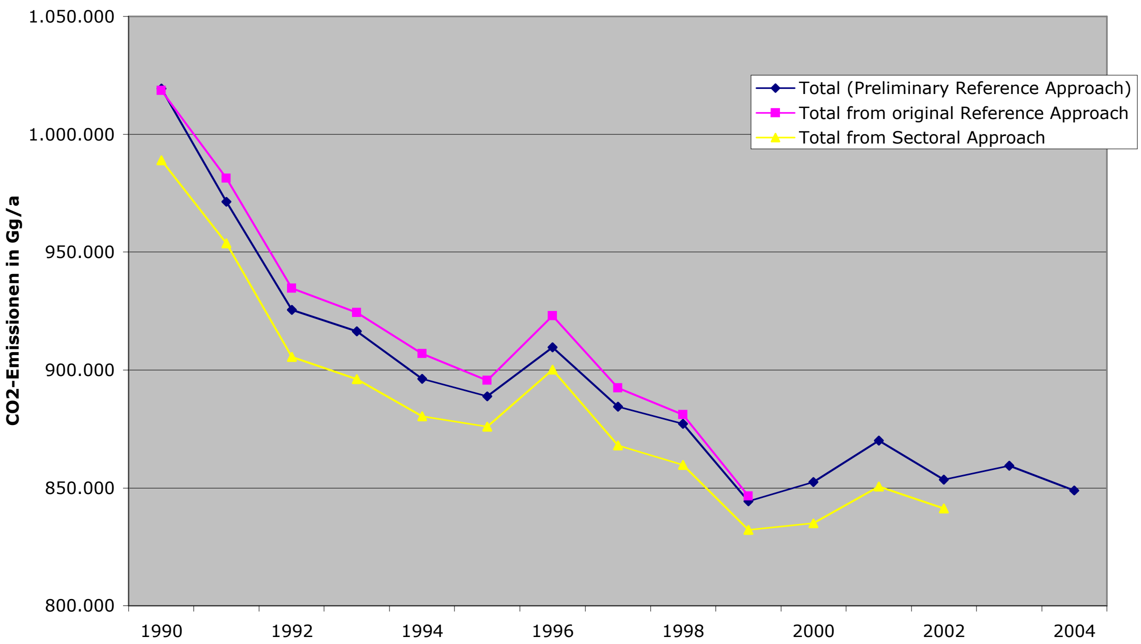
The following figure shows Germany's combustion-related CO_2 emissions for the years 1990 to 2004. A total of three time series – one for each calculation approach – are shown. In the lower figure, the deviations between the preliminary reference approach developed here and the values reported officially to the Framework Convention on Climate and to the EU, pursuant to the reference and sectoral approaches, are also compared.

Figure 64: Comparison of combustion-related CO_2 emissions determined via different calculation approaches[77]



Source: Own calculations

Figure 65: Deviation of the preliminary reference approach (preliminary) from the reference approach (original) and the sectoral approach[78]



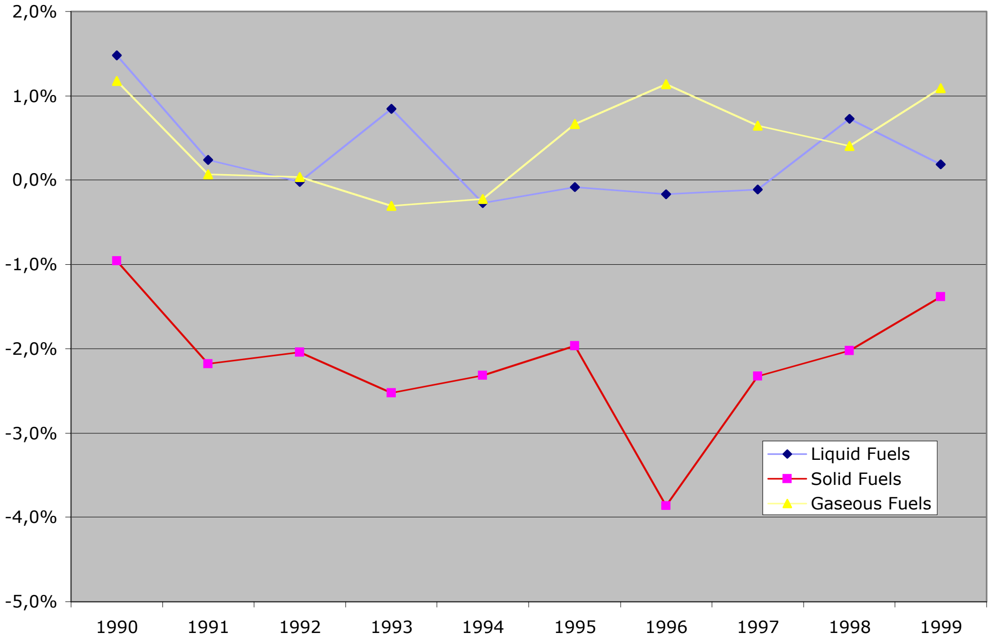
Source: Own calculations

[77] deviation in %
[78] CO_2 emissions in Gg / a

The comparison of the different calculation approaches shows that the three curves are highly similar – with regard to both their separation and their progressions. And yet not only does the preliminary reference approach developed here diverge from the other two approaches; the other two approaches diverse from each other as well. For all of the years under consideration, the emissions pursuant to the preliminary reference approach lie between 0.5 and 3% below the values calculated via the reference approach. In comparison to the sectoral approach, the emissions are up to 2% higher, however. At the same time, in all years under consideration, the preliminary reference approach is clearly more similar to the sectoral approach than the final reference approach is.

The curves showing the deviations between the preliminary reference approach and the sectoral approach, and between the preliminary reference approach and the reference approach, are largely similar in their progression. This points to the presence of systematic error sources in the overall approach – in the assumptions and estimates involved.

Figure 66: Deviation of the preliminary reference approach from the original reference approach (CO_2 emissions by fuels)



Source: Own calculations

A comparison of the preliminary reference approach's deviations from the final reference approach, by fuel categories, shows that emissions from liquid and gaseous fuels, as obtained by the two calculation methods, diverge only slightly from each other (normally, by not more than 1 %).

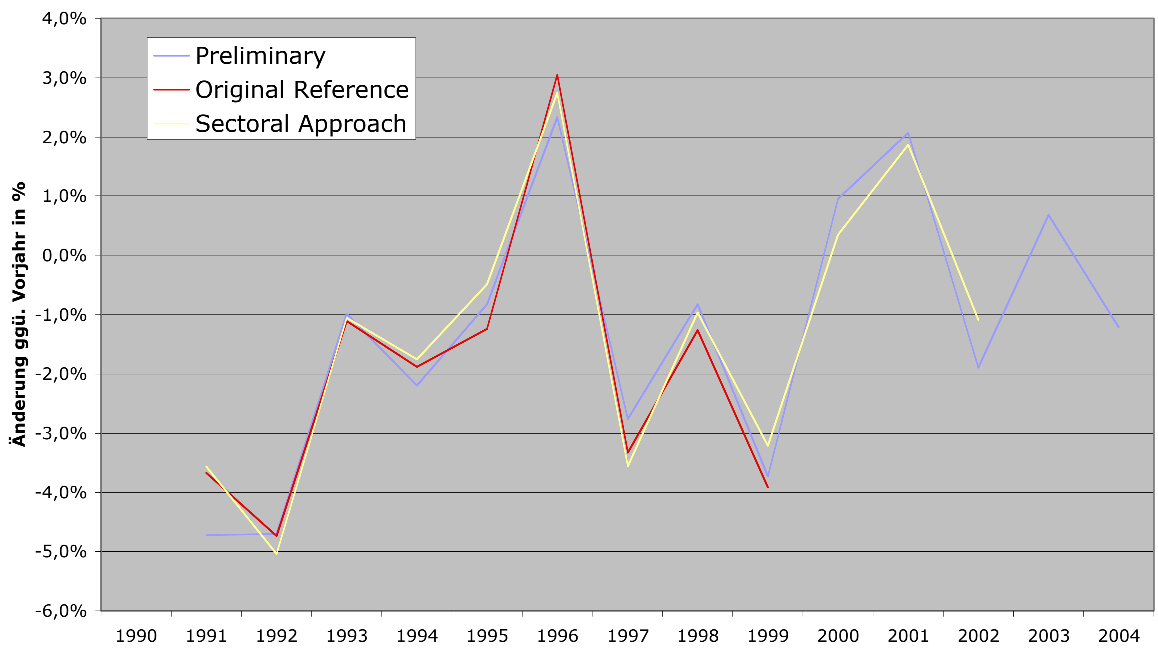
On the other hand, in all relevant years the preliminary approach has underestimated emissions from solid fuels by 1 to 4 %.

Another (even more) interesting aspect, apart from the preliminary reference approach's accuracy in determining absolute levels of CO_2 emissions, is that of how accurately the preliminary approach shows the changes in emissions between the years under consideration[79].

The following figure shows percentage changes in CO_2 emissions, over the previous year, for all three calculation approaches. A large degree of agreement between all three methods is apparent. In general, all methods show a similar trend direction. On the other hand, the approaches differ somewhat in their results for the magnitude of the change. The year 1995, in which the preliminary approach departs considerably from the other two approaches in terms of magnitude (but not in direction), particularly stands out. Possibly, this may be explained – partly, at least – as a result of the Energy Balance conversion that took place as of this cut-off year.

On an average for the years 1994 to 1999, the reference approach lay by 0.3 percentage points above or below the sectoral approach in its result for the emissions changes. The corresponding figure for the preliminary reference approach, by contrast, was 0.4 percentage points.

Figure 67: Change in CO_2 emissions with respect to the previous year, in %



Source: Own calculations

In general, the CO_2-emissions trends for the years under consideration, as determined by the preliminary approach, were always correct in terms of direction. The only departures from the final values were seen in the magnitudes of the changes. The same may be said with regard to emissions from liquid and gaseous fuels and – with some restrictions – to those from solid fuels as well. The trend for the latter was not given correctly for the years 1995 to 1997, however. Ultimately, this was the factor responsible for the somewhat poorer precision with regard to the overall result for these years.

79 Since energy consumption and CO_2 emissions are strongly influenced by fixed structures, they change only slowly over time. As a result, good approximations, covering short periods of time, can be achieved via linear extrapolation or reliance on the relevant previous year's values. A directionally reliable, highly quantitatively precise estimate of changes from the previous year would truly enhance findings, however.

As a rule, the emissions-calculation changes resulting from the corrections of the preliminary figures in the evaluation tables are relatively minor. Between the Energy Balance evaluation tables published in 2004 and those of 2005, only minor differences occurred in the figures pertinent here for the years 2002 and 2003. Inputs of petroleum products in the energy sector were upwardly corrected by 20 PJ in 2002 and by 54 PJ in 2003. Inputs in households were upwardly corrected by only 12 PJ in 2003. For 2003, this change results in a CO_2-emissions increase of about 4.8 million t, or of nearly 0.6 %. For 2002, the change is nearly 1.5 million t or nearly 0.2 %.

On the whole, then, the preliminary method for estimating results of the reference approach, on the basis of the evaluation tables for the Energy Balance, may be considered good. In terms of both absolute levels and of identifying chronological trends, it shows good agreement with the figures obtained on the basis of the complete database.

Care has to be taken solely when the two time series are related to each other. As a result of the slight difference in levels, a major error can occur in comparison of the different approach's chronological progressions. In pertinent cases, it would be more useful to relate time-series information only to a single calculation approach, in order to rule out the possibility of such effects.

Potential for improvement may exist in the area of solid fuels; in that area, lacking figures normally become available, on time, via separate balances, and thus can sometimes be used to supplement the evaluation tables for the Energy Balance.

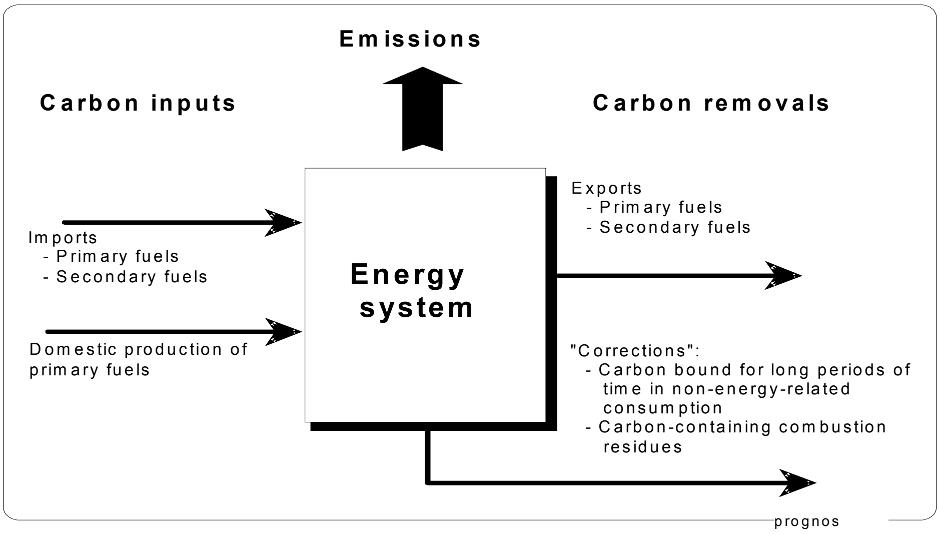
13.11 Analysis of the reference approach

13.11.1 Methodological issues

The basic principle of the reference approach is to work with an aggregated carbon balance for the energy sector. The quantity of carbon emitted from the energy sector (per annum) is then calculated as the difference between the quantities of carbon input (entered) and output (removed) together with the relevant energy resources (cf. Figure 68).

The carbon inputs are linked to imports of primary energy resources (such as petroleum, natural gas) and secondary energy resources (e.g. heating oil, motor gasoline, coke) and to domestic production of primary energy resources. Carbon outputs are linked to exports of primary and secondary energy resources and bunkering (fuel consumption by marine shipping and international air traffic). The reference approach therefore includes adjustments to the carbon balance to allow for non-emissions-relevant quantities of carbon. These take account of carbon output in combustion residues containing carbon (*fraction of carbon oxidised)* and long-term-fixed carbon in products sited downstream from non-energy-related consumption of energy resources (*fraction of carbon stored*; e.g. use of naphtha in plastics production).

The correction factors are designed to refine calculation of the CO_2 emissions figures as carried out using the simple input/output balance of energy resources. In calculation of the "*fraction of carbon stored*" correction factors, non-combustion-related emissions, particularly solvent and process emissions, are also included in the balance as "*carbon stored*", in addition to the carbon actually stored in long-lived products. The remaining share, included in the balance as *released carbon*, then actually consists only of combustion-related CO_2 emissions (e.g. waste incineration, internal fuel consumption by steam crackers). Within the downstream product chains of non-energy-related consumption, imports and exports of intermediate and finished products are included in the balance in keeping with the "*producer principle*" – in other words, imports are disregarded, and exports are included in the CO_2 balance.



(Prognos, 2000)

Figure 68: Basic principle of the IPCC reference approach (Prognos, 2000)

The IPCC reference approach is designed to calculate the potential CO_2 emissions from the energy resources used in a given country. The potential emissions are not the same as the actual emissions.

In applying the IPCC reference approach in Germany, the principal methodological assertions outlined below were made.

13.11.1.1 Hard coal

The German Energy Balance does not differentiate according to different hard-coal types. In German coal statistics, domestic production of hard coal is divided into bright-burning coal, rich coal, forge coal, lean coal and anthracite coal, however. The same breakdown is also used when applying the IPCC approach. However, as this system differs from the IPCC classification of hard coal ("*bituminous coal*") into anthracite, coke coal and others, only one collective category, *bituminous coal*, is shown in the IPCC tables. Differentiated calculation for domestic production, by types of coal, is carried out as part of a special calculation (cf. the R&D project on use of the IPCC reference approach for determining combustion-related CO_2 emissions in Germany, UFOPLAN97).

The same applies to hard coal imports: Imported coal has different characteristic values, depending on its country of origin. On the basis of the foreign trade statistics of the Federal Statistical Office and STATISTIK DER KOHLENWIRTSCHAFT (2004) (coal-industry statistics), reporting of hard-coal imports will be differentiated by countries of origin when the IPCC method is used. This makes it possible to allow for the ways in which changes in import-origin structures influence carbon inputs.

13.11.1.2 Lignite

The IPCC procedure only envisages one category in this area, "*lignite*". A special differentiating calculation is thus carried out to allow for lignite's special importance in

Germany (cf. the R&D project on use of the IPCC reference approach for determining combustion-related CO_2 emissions in Germany, UFOPLAN97):

- For domestic production, a differentiation is made according to the main mining regions of Rhineland, Lausitz, central Germany, Helmstedt and others (Borken and Wölfersheim, both of which were decommissioned on 31 October 1991). The production quantities are regularly reported in coal-mining-industry statistics.
- Amongst imports, a distinction was made between lignite and hard lignite (Czech Republic), in keeping with the Energy Balance statistics. Since 2003, hard lignite from the Czech Republic is no longer used in German power stations.
- Exports and stock changes are not further differentiated and are taken from the data in the Energy Balance.

13.11.1.3 Natural gas

Natural gas, petroleum gas and pit gas, which are shown separately in the German Energy Balance, are combined under "*natural gas*". The characteristic values of natural gas imports differ, depending on their origin. In a procedure similar to that used for hard coal, therefore, a special calculation is carried out that differentiates natural gas imports by their principal countries of origin (Russia, The Netherlands, Norway).

13.11.1.4 Petroleum imports

In the Federal Republic of Germany, petroleum imports account for a large proportion of the input of carbon into the energy system. Changes in the import structure, i.e. in the shares of individual countries of origin or in oil quality, can therefore lead to tangible fluctuations in the quantity of carbon imported via crude oil. On the other hand, the carbon content in crude oil fluctuates within a comparatively narrow range, between approximately 82% and 87%[80]. These limits are extreme values. The fluctuation range in the crude oil mix consumed annually is significantly lower. For this reason, changes in the composition of crude oil imports have only a limited influence on the average carbon content of crude oil imports.

Nevertheless, in applying the IPCC reference approach for calculating the carbon content in crude oil imports, a special calculation was envisaged and implemented on the basis of principal importing countries and qualities as well as oil fields (analogous to the procedure for hard coal and natural gas). The quantities given (crude oil imports on the basis of production regions and types) are not published, but may be obtained from the industry association, *Association of the German Petroleum Industry* (MWV), in Hamburg. No data is available on the carbon content of the individual crude oil types, since this does not represent a relevant factor in petroleum processing. The specific gravity of petroleum and its carbon content are known to correlate empirically, however (MARLAND et al, 1983). The carbon content of the individual crude oil types has been estimated on the basis of this correlation and of published data on specific gravity *("API Gravity"*[81]).

13.11.2 Databases

The principal databases for application of the IPCC reference approach in Germany are summarised below:

80) The global average is approximately 84.5 %.
81) The specific gravities are available for all varieties, with the exception of Russian oil (OIL & GAS JOURNAL DATA BOOK 1997). Average values were used for Russian petroleum.

Energy data: Energy data is based on the currently available (1990 to 1999) energy balances of the Working Group on Energy Balances (AGEB). As these balances are not yet available for the years 2000 and 2003, it was not possible to apply the reference approach here in a fully detailed manner. Past reviews of submitted emissions inventories have repeatedly found that failure to use the IPCC reference approach for the entire time series is a deficit. For this reason, the possibility of using the existing analysis tables for the Energy Balance, which contain recent, but highly aggregated, data, was again reviewed. This led to development of a simplified procedure, based on these analysis tables and drawing on pragmatic considerations (transfer of relationships between fuel inputs and fuel-consumption data, and continued use of the structure for non-energy-related fuel consumption), that this year, for the first time, has made it possible to provide tentative reference-approach results for the previously missing years. These results will be appropriately supplanted, however, upon publication of detailed energy balances in the framework of recalculations. For the main primary fuels petroleum, natural gas, hard coal and lignite, the reference approach differentiates further on the basis of type or geographical origin. Data obtained from the energy statistics of the respective associations is used to achieve such differentiation.

Fuel characteristics / emission factors: This information is based on the GEMIS database (ÖKO-INSTITUT), supplemented with data from the Jülich Research Centre (from the IKARUS project).

Downstream product chains of non-energy-related consumption: A study by the Fraunhofer Institute for Systems and Innovation Research (ISI) provides the main database. As this did not provide a complete data foundation for calculating carbon storage, it was supplemented with our own estimates.

13.11.3 Results

The CO_2 emissions calculated using the IPCC reference approach decreased by almost 17 % between 1990 and 1999. This is roughly consistent with the emissions trend in the detailed source-category-related calculations for energy-related CO_2 emissions.

On average, the results of the reference approach for the period under review are 3 % above the CO_2 emissions calculated in detail.

Around 2/3 of these deviations are attributable to differences in the emission factors or average carbon contents of the energy resources, which cannot be calculated as precisely with the reference approach as with the source-category-specific approach. The remaining deviations are attributable to systematic differences between the two methods at the level of underlying energy consumption – specifically, in consideration of non-energy-related consumption, waste incineration, statistical differences and losses in the transformation sector of the energy system, including energy consumption by natural-gas-pipeline compressors (cf. Figure 69).

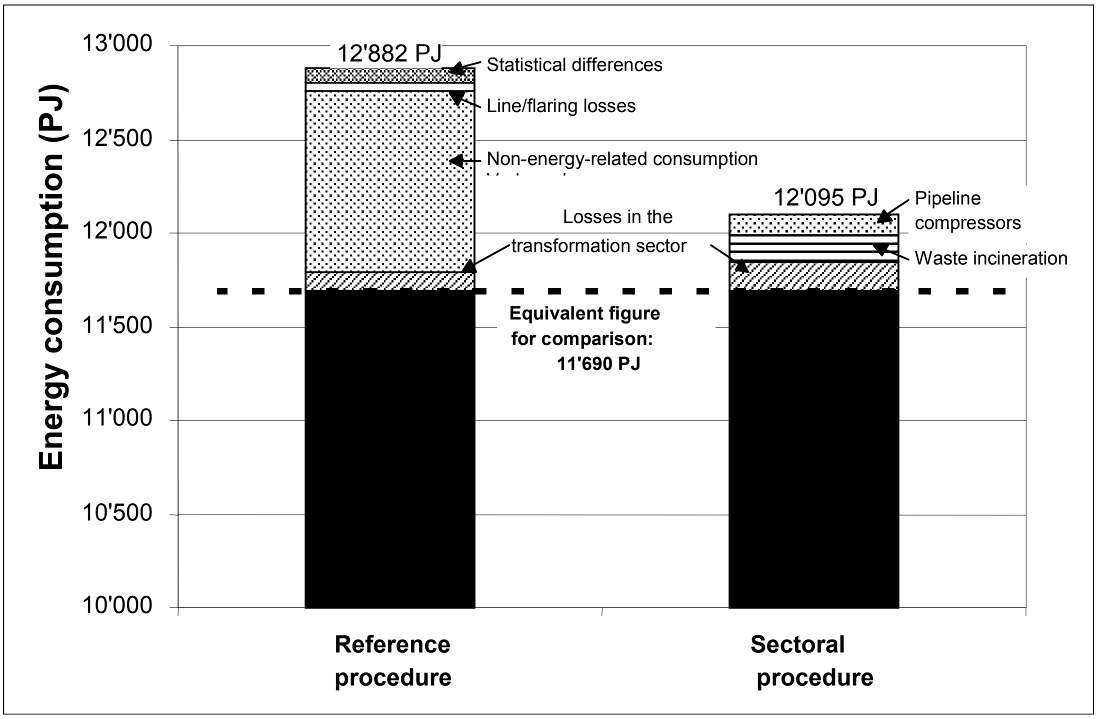


Figure 69: Systematic differences between the reference approach and the source-category-specific approach (1990)

13.11.4 Planned improvements

Precise summing and assessment of emissions from non-energy-related fuel consumption plays a key role in comparison of results of the reference approach with those of detailed sectoral CO_2 calculation. In the reference approach, these emissions are taken into account via determination of the amounts of carbon stored in products for long periods of time. In the detailed sectoral calculations that are currently carried out for Germany, such emissions are taken into account only to a limited extent (for example, in combustion of fossil fuels). The first studies in this area have shown that emissions from non-energy-related fuel consumption are of the order of about 1 to 2 % of total CO_2 emissions. This is the amount, therefore, by which the results of the two calculation methods would differ. One of the emphases of ongoing efforts to improve inventories with respect to CO_2 emissions is to precisely analyse such methodological issues, and make any necessary modifications, with regard to both the reference approach and detailed sectoral emissions calculation.

In applying the IPCC reference approach at the international level, special calculation of the ”*fraction of carbon stored*”, in order to correct potential CO_2 emissions by subtracting the carbon stored in the downstream product chains of non-energy-related consumption, would seem to be an extremely involved process:

- On the one hand, a considerable amount of data must be collected, and this is inconsistent with the reference approach's objective of minimising data requirements – not all the necessary data is available even in Germany. This problem is further complicated by delimitation problems in determining the "fraction of carbon stored", problems which hinder the international comparability of results.
- On the benefits side, this contrasts with only a limited ”accuracy gain” for most countries, purely by virtue of the fact that total non-energy-related consumption generally accounts for no more than 10 % of primary fuel consumption. In Germany,

the accuracy gain is between 5 and 6 %. Furthermore, it is doubtful whether the results could be refined by using the default values proposed by the IPCC, since those values are general estimates which fail to allow for the specific situations prevailing in individual countries.

14 ANNEX 3: OTHER DETAILED METHODOLOGICAL DESCRIPTIONS FOR INDIVIDUAL SOURCE OR SINK CATEGORIES

14.1 Other detailed methodological descriptions for the source category "Energy" (1)

14.1.1 Revision of the activity rates for stationary combustion systems in the new German Länder for the year 1990 (1.A)

The problems in 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 previously reported figures 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 now 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 assigned quantities, were explicitly reviewed for any gaps, completed and corrected as necessary and substantiated".

With use, inter alia, of the original data sources listed below, realistic fuel consumption figures were derived. These were then compared, in light of the structure of the BEU model (Balance of Emissions Causes), to the CSE data, in order to identify relevant data differences and gaps:

- Energiewirtschaftlicher Jahresbericht 1990 für die NBL, Band 1a (annual energy-sector report for the new German Länder, for the year 1990, Volume 1a)
- Accounting of the former GDR's energy balance for 1988
- Overall energy balance (Gesamtenergiebilanz) for 1989 for the economic area of the former GDR
- Overall energy balance for 1990, for the economic area covered by the five new Länder in the Federal Republic of Germany
- 1992 Statistical Yearbook of the Federal Republic of Germany
- Precise determination of energy requirements trends for the areas of business and industry, the public and other consumers, for the period until 2005 (in these studies, specific energy consumption and relevant production quantities for 1990, in the area of energy-intensive products, were estimated)
- A revision, carried out by the Federal Environmental Agency, relative to process combustion
- Own calculations

Some of the primary data lacking for the year 1990 was filled in via interpolation, from data for previous and subsequent years, and via supporting assessments by experts.

The 1990 figures for inputs of fuels, including hard coal and lignite, liquid fuels, gases, and substitute fuels – such as waste or other petroleum products – and for use of renewable energies, were brought into a form suitable for comparison. The following two sub-chapters present the relevant methodological foundations and results.

14.1.1.1 System and procedure

14.1.1.1.1 Basic system applied to power stations

The term "stationary combustion systems" applies to all power stations that produce electric power, or electric power and heat, that is then used for industrial processes or for heating purposes. Boiler systems in district heating stations, and consumption of auxiliary energy in the transformation sector, must also be taken into account. Furthermore, final-energy consumption in industrial boilers for process combustion, in the "other mining" and manufacturing sectors, must also be included.

Power stations are subdivided by types into the categories of public thermal power stations and gas turbine systems, mine (pit) power stations and industrial power stations (refinery power stations are listed separately).

In addition, the combustion systems of these power-station types are subdivided into large combustion systems (Großfeuerungsanlagen; GFA), in keeping with the relevant definition in the 13th Federal Immission Control Ordinance (BimSchV), and in systems falling under the Technical Instructions on Air Quality Control (TA Luft).

Finally, within the category of industrial power stations, fuels used in power stations of German Railways are listed separately.

14.1.1.1.2 Procedure

In a first step, the entire set of relevant power stations, as it existed in 1990, was entered into a database, together with information relative to electrical outputs, steam heat production and fuel consumption.[82] This set comprised a total of 229 power stations. It did not include the Greifswald and Rheinsberg power stations, nor did it include hydroelectric and storage power stations.

The lignite sector was subdivided by regions into the Lausitz and Mitteldeutschland coal fields, since the two fields differ in their CO_2 emission factors, and the differences have to be taken into account for calculation of CO_2 emissions.

The new power-station database, with parameters as described above, was then used for recalculations, oriented to specific power-station types, covering all fuels used for electricity production, industrial process heat and district heat – as listed in the relevant Energy Balance lines.

In addition – i.e. apart from work with figures in the new power-station database – fuel consumption for district-heat production in public district-heating stations, in keeping with the listing in Energy Balance line 18, was determined.

[82] In keeping with definitions pertinent to the energy-sector statistics of the former GDR, at the end of each calendar year all power-station operators reported data, as required under central provisions, to the ORGREB – the power station institute (Institut für Kraftwerke) in Vetschau – which then used the data to prepare its annual general report [EWJB 90]. This report appeared for the last time in 1990, in a shortened form; the pertinent detailed summary of power stations was then submitted only internally, however, to the then IfE.

As a third position within the transformation balance, an entry was made in Energy Balance line 45 for fuel inputs for auxiliary energy consumption in the categories of heat in the petroleum industry, drying heat in production of lignite briquettes and lignite dust, and auxiliary energy consumption in coking plants and local gas works.

In the final energy consumption sector, fuel consumption in the various types of power stations, for supplied industrial process heat, was entered in Energy Balance line 73. In addition, i.e. apart from work with the figures in the new power-station database, this line is also used for fuel consumption in industrial boilers and in process combustion. For a total of eleven identified key processes, it was possible to allocate fuel consumption for process combustion specifically to relevant industrial sectors; the remaining processes were combined to form an aggregate.

14.1.1.2 Results

The basis for the analysis presented here is the overall energy balance (Gesamtenergiebilanz) of 1990. In terms of levels, consumption of all fuels remained the same; there were no major deviations. This also means that the revision has not significantly changed pertinent CO_2 emissions.

Differences from the original energy balance result solely in allocation of fuel inputs to individual balance lines. The total of all fuels used in power stations for electricity production shows a reduction in consumption of 8,640 TJ. With respect to the originally listed energy consumption for power production, amounting to 1,046,012 TJ, a relative transfer of fuel inputs results, amounting to a transfer of 0.83 % from the transformation sector into the final-energy consumption sector. The consumption increase in the latter sector, seen in the "other mining" and manufacturing areas, amounts to 8,640 TJ.

Originally, the CSE contained a total of 268 time series for source categories 1.A.1 and 1.A.2 (not including private households / small consumers and the military sector). Now, through use of new data sources and pertinent evaluation, a more differentiated allocation and presentation results, with some new structural elements and with a total of 360 time series. The new divisions include the regional breakdown of the lignite sector into the Mitteldeutschland and Lausitz coal fields. This quantitative energy data relative to stationary combustion systems, in time series, is being provided in fulfillment of reporting obligations in the framework of the National Inventory of greenhouse gases (NIR 2006).

The relevant fuel-consumption figures have been obtained via intensive data research and via calculations (multi-stage, in some cases) and then allocated, in pertinent Energy Balance lines, to power stations and/or station or industrial boilers. The following tables provide a relevant overview.

Table 115: Fuel inputs for electricity production in public thermal, mine and industrial power stations (new German Länder, 1990)

	Units	Electricity production in large combustion systems of public thermal power stations	Electricity production in gas turbines of public thermal power stations	Electricity production in large combustion systems of power stations of the lignite-mining sector	Electricity production in large combustion systems of other industrial thermal power stations	Of these, railways' power stations	Electricity production in other industrial thermal power stations (TA-Luft)	Of these, railways' power stations	Electricity generation in large combustion systems of refinery power stations	Total
Installed output	**MW**	**14.544**	**1.253**	**2.872**	**1.401**	**44**	**118**	**2**	**682**	**20.870**
Bottleneck capacity	**MW**	**11.367**	**989**	**1.727**	**574**	**20**	**26**	**1**	**236**	**14.918**
Boiler efficiency	%	82,64%	94,72%	80,52%	81,44%	79,72%	73,17%	80,25%	82,96%	82,30%
Electricity production	**GWh**	**74.084**	**92**	**13.035**	**4.219**	**169**	**191**	**1**	**1.926**	**93.546**
Heat for electricity production	**TJ**	**685.440**	**1.175**	**115.910**	**32.919**	**2.490**	**1.606**	**3**	**16.747**	**853.797**
Fuel for electricity production	**TJ**	**829.386**	**1.240**	**143.944**	**40.419**	**3.124**	**2.195**	**3**	**20.187**	**1.037.372**
Crude lignite	TJ	813.525	0	124.106	18.378	3.088	714	3	7.881	**964.605**
> Lausitz coal field	TJ	*662.638*	*0*	*97.829*	*4.551*	*504*	*165*	*0*	*0*	***765.183***
> Mitteldeutschland coal field	TJ	*150.887*	*0*	*26.277*	*13.827*	*2.584*	*550*	*3*	*7.881*	***199.422***
- Lignite briquettes	TJ	488	0	690	1.791	0	402	0	24	**3.394**
> Lausitz coal field	TJ	98	*0*	*171*	*398*	*0*	*200*	*0*	0	***867***
> Mitteldeutschland coal field	TJ	390	*0*	*519*	*1.392*	*0*	*203*	*0*	24	***2.527***
- Dry coal	TJ	0	0	5.941	0	0	0	0	238	**6.178**
> Lausitz coal field	TJ	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	***0***
> Mitteldeutschland coal field	TJ	*0*	*0*	*5.941*	*0*	*0*	*0*	*0*	*238*	***6.178***
- Lignite semi-coke	TJ	1	0	5.462	2.113	0	223	0	876	**8.674**
> Lignite low-temperature coke	TJ	*1*	*0*	*5.462*	*2.113*	*0*	*223*	*0*	*876*	**8.674**
> Lignite high-temperature coke	TJ	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	**0**
- Hard coal	TJ	37	0	1.047	2.787	0	286	0	0	**4.157**
- Hard-coal coke	TJ	0	0	0	0	0	0	0	0	**0**
- Hard-coal briquette	TJ	0	0	0	0	0	0	0	0	**0**
- Firewood	TJ	0	0	0	0	0	0	0	0	**0**
- Light heating oil	TJ	0	94	0	0	0	0	0	0	**94**
- Heavy heating oil	TJ	6.984	0	162	2.205	13	12	0	883	**10.245**
- Diesel fuel	TJ	0	146	0	0	0	0	0	0	**146**
- Natural gas	TJ	7.705	1.000	77	9.271	0	31	0	4.322	**22.406**
> imported natural gas	TJ	*5.663*	*1.000*	*25*	*4.835*	*0*	*0*	*0*	*4.322*	**15.845**
> domestic natural gas	TJ	*2.042*	*0*	*53*	*4.436*	*0*	*31*	*0*	*0*	**6.561**
- LP gas	TJ	0	0	0	0	0	0	0	0	**0**
- Gas from sewage treatment	TJ	0	0	0	0	0	0	0	0	**0**
- City gas / other gas	TJ	29	0	2.877	1.287	0	93	0	1.318	**5.604**
- Blast furnace gas	TJ	0	0	0	1.940	0	0	0	0	**1.940**
- Special fuels	TJ	618	0	3.582	648	23	434	0	4.646	**9.926**
		↓ **EB line 13**	↓ **EB line 13**	↓ **EB line 14**	↓ **EB line 15**		↓ **EB line 15**		↓ **EB line 15**	

Table 116: Fuel inputs for industrial heat production in public thermal, mine and industrial power stations (new German Länder, 1990)

	Units	Heat production in large combustion systems of public thermal power stations	Heat production in large combustion systems of power stations of the lignite-mining sector	Heat production in large combustion systems of other industrial power stations	Of these, railways' power stations	Heat production in combustion systems of other industrial power stations (TA-Luft)	Of these, railways' power stations	Heat production in large combustion systems of refinery power stations	Total
Boiler efficiency	%	82,44%	78,82%	79,27%	79,21%	74,27%	80,25%	83,06%	79,48%
Industrial heat production	TJ	3.611	128.533	100.426	171	10.291	158	44.878	287.740
Fuel for industrial heat	TJ	4.380	163.065	126.687	216	13.856	196	54.031	362.020
Crude lignite	TJ	4.122	150.799	60.263	207	6.892	196	18.303	**240.379**
> Lausitz coal field	TJ	1.759	96.135	10.294	207	1.743	0	0	**109.931**
> Mitteldeutschland coal field	TJ	2.364	54.664	49.969	0	5.149	196	18.303	**130.448**
- Lignite briquettes	TJ	0	333	8.084	0	3.640	0	0	**12.057**
> Lausitz coal field	TJ	0	79	3.328	0	2.021	0	0	**5.428**
> Mitteldeutschland coal field	TJ	0	255	4.756	0	1.619	0	0	**6.630**
- Dry coal	TJ	0	2.912	0	0	0	0	0	**2.912**
> Lausitz coal field	TJ	0	0	0	0	0	0	0	**0**
> Mitteldeutschland coal field	TJ	0	2.912	0	0	0	0	0	**2.912**
- Lignite semi-coke	TJ	0	2.677	6.199	0	944	0	58	**9.878**
> Lignite low-temperature coke	TJ	0	2.677	6.199	0	944	0	58	**9.878**
> Lignite high-temperature coke	TJ	0	0	0	0	0	0	0	**0**
- Hard coal	TJ	0	378	10.353	0	951	0	0	**11.682**
- Hard-coal coke	TJ	0	0	0	0	0	0	0	**0**
- Hard-coal briquette	TJ	0	0	0	0	0	0	0	**0**
- Firewood	TJ	0	0	0	0	0	0	0	**0**
- Light heating oil	TJ	0	0	0	0	0	0	0	**0**
- Heavy heating oil	TJ	113	119	9.070	0	303	0	2.520	**12.124**
- Diesel fuel	TJ	0	0	0	0	0	0	0	**0**
- Natural gas	TJ	145	0	26.000	0	606	0	8.933	**35.684**
> imported natural gas	TJ	2	0	12.887	0	0	0	8.933	**21.822**
> domestic natural gas	TJ	143	0	13.113	0	606	0	0	**13.862**
- LP gas	TJ	0	0	0	0	0	0	0	**0**
- Gas from sewage treatment	TJ	0	0	0	0	0	0	0	**0**
- City gas / other gas	TJ	0	3.119	1.988	0	0	0	12.599	**17.706**
- Blast furnace gas	TJ	0	0	1.479	0	0	0	0	**1.479**
- Special fuels	TJ	0	2.728	3.252	9	521	0	11.619	**18.120**
		↓ **EB line 73**	↓ **EB line 45 / 73**	↓ **EB line 73**		↓ **EB line 73**		↓ **EB line 45**	

Table 117: Fuel inputs for district-heat production in public thermal, mine and industrial power stations (new German Länder, 1990)

	Units	Heat production in large combustion systems of public thermal power stations	Heat production in gas turbines of public thermal power stations	Heat production in large combustion systems of power stations of the lignite-mining sector	Heat production in large combustion systems of other industrial power stations	Of these, railways' power stations	Heat production in combustion systems of other industrial power stations (TA-Luft)	Of these, railways' power stations	Heat production in large combustion systems of refinery power stations	**Total**
Boiler efficiency	%	83,26%	68,11%	79,30%	80,59%	79,37%	76,97%		85,02%	82,57%
District-heat production	**TJ**	**109.565**	**167**	**10.874**	**14.253**	**723**	**2.659**	**0**	**3.952**	**141.469**
Fuel for district heat	**TJ**	**131.588**	**245**	**13.713**	**17.686**	**911**	**3.454**	**0**	**4.648**	**171.334**
Crude lignite	TJ	87.000	0	10.557	8.770	880	1.128	0	1.023	**108.478**
> Lausitz coal field	TJ	*46.503*	*0*	*6.603*	*4.321*	*645*	*598*	*0*	*0*	***58.024***
> Mitteldeutschland coal field	TJ	*40.497*	*0*	*3.954*	*4.449*	*235*	*530*	*0*	*1.023*	***50.453***
- Lignite briquettes	TJ	7.939	0	503	2.462	0	1.247	0	0	**12.151**
> Lausitz coal field	TJ	*1.012*	*0*	*333*	*780*	*0*	*722*	*0*	*0*	***2.847***
> Mitteldeutschland coal field	TJ	*6.927*	*0*	*170*	*1.682*	*0*	*525*	*0*	*0*	***9.304***
- Dry coal	TJ	0	0	169	0	0	0	0	0	**169**
> Lausitz coal field	TJ	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	***0***
> Mitteldeutschland coal field	TJ	*0*	*0*	*169*	*0*	*0*	*0*	*0*	*0*	***169***
- Lignite semi-coke	TJ	64	0	0	165	0	11	0	0	**240**
> Lignite low-temperature coke	TJ	64	0	0	165	0	11	0	0	**240**
> Lignite high-temperature coke	TJ	0	0	0	0	0	0	0	0	**0**
- Hard coal	TJ	1.282	0	2.090	1.503	0	907	0	0	**5.782**
- Hard-coal coke	TJ	0	0	0	0	0	0	0	0	**0**
- Hard-coal briquette	TJ	0	0	0	0	0	0	0	0	**0**
- Firewood	TJ	0	0	0	0	0	0	0	0	**0**
- Light heating oil	TJ	0	245	0	0	0	0	0	0	**245**
- Heavy heating oil	TJ	13.820	0	50	504	1	0	0	3	**14.378**
- Diesel fuel	TJ	0	0	0	0	0	0	0	0	**0**
- Natural gas	TJ	20.956	0	2	3.891	0	150	0	501	**25.500**
> imported natural gas	TJ	13.268	0	1	1.641	0	0	0	501	**15.410**
> domestic natural gas	TJ	7.688	0	1	2.250	0	150	0	0	**10.089**
- LP gas	TJ	0	0	0	0	0	0	0	0	**0**
- Gas from sewage treatment	TJ	0	0	0	0	0	0	0	0	**0**
- City gas / other gas	TJ	134	0	205	223	0	0	0	2.931	**3.494**
- Blast furnace gas	TJ	0	0	0	0	0	0	0	0	**0**
- Special fuels	TJ	391	0	136	167	29	11	0	190	**896**
		↓ **EB line 18**	↓ **EB line 18**	↓ **EB line 18**	↓ **EB line 18**		↓ **EB line 18**		↓ **EB line 18**	

Table 118: Total fuel inputs in public thermal, mine and industrial power stations (new German Länder, 1990)

	Units	Total heat production in large combustion systems of public thermal power stations	Total heat production in gas turbines of public thermal power stations	Total heat production in large combustion systems of power stations of the lignite-mining sector	Total heat production in large combustion systems of other industrial power stations	Of these, railways' power stations	Total heat production in combustion systems of other industrial power stations (TA-Luft)	Of these, railways' power stations	Total heat production in large combustion systems of refinery power stations	**Total**
Boiler efficiency	%	82,73%	90,33%	79,61%	79,87%	79,62%	74,63%	80,25%	83,15%	81,68%
Total heat production	**TJ**	**798.616**	**1.342**	**255.317**	**147.599**	**3.384**	**14.556**	**160**	**65.576**	**1.283.006**
Fuel for total heat	**TJ**	**965.354**	**1.486**	**320.722**	**184.792**	**4.251**	**19.505**	**200**	**78.866**	**1.570.725**
Crude lignite	TJ	**904.647**	**0**	**285.462**	**87.411**	**4.175**	**8.735**	**200**	**27.207**	**1.313.462**
> Lausitz coal field	TJ	***710.899***	***0***	***200.568***	***19.166***	*1.356*	***2.506***	*0*	***0***	***933.138***
> Mitteldeutschland coal field	TJ	***193.748***	***0***	***84.895***	***68.245***	*2.819*	***6.229***	*200*	***27.207***	***380.323***
- Lignite briquettes	TJ	**8.427**	**0**	**1.526**	**12.336**	**0**	**5.290**	**0**	**24**	**27.603**
> Lausitz coal field	TJ	***1.111***	***0***	***582***	***4.506***	*0*	***2.944***	*0*	***0***	***9.142***
> Mitteldeutschland coal field	TJ	***7.317***	***0***	***944***	***7.830***	*0*	***2.346***	*0*	***24***	***18.461***
- Dry coal	TJ	**0**	**0**	**9.021**	**0**	**0**	**0**	**0**	**238**	**9.259**
> Lausitz coal field	TJ	***0***	***0***	***0***	***0***	*0*	***0***	*0*	***0***	***0***
> Mitteldeutschland coal field	TJ	***0***	***0***	***9.021***	***0***	*0*	***0***	*0*	***238***	***9.259***
- Lignite semi-coke	TJ	**65**	**0**	**8.140**	**8.477**	**0**	**1.177**	**0**	**934**	**18.792**
> Lignite low-temperature coke	TJ	**65**	**0**	**8.140**	**8.477**	**0**	**1.177**	**0**	**934**	**18.792**
> Lignite high-temperature coke	TJ	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
- Hard coal	TJ	**1.320**	**0**	**3.515**	**14.643**	**0**	**2.144**	**0**	**0**	**21.621**
- Hard-coal coke	TJ	0	0	0	0	0	0	0	0	0
- Hard-coal briquette	TJ	0	0	0	0	0	0	0	0	0
- Firewood	TJ	0	0	0	0	0	0	0	0	0
- Light heating oil	TJ	**0**	**339**	**0**	**0**	**0**	**0**	**0**	**0**	**339**
- Heavy heating oil	TJ	**20.917**	**0**	**331**	**11.779**	**14**	**315**	**0**	**3.406**	**36.748**
- Diesel fuel	TJ	**0**	**146**	**0**	**0**	**0**	**0**	**0**	**0**	**146**
- Natural gas	TJ	**28.807**	**1.000**	**79**	**39.162**	**0**	**787**	**0**	**13.755**	**83.590**
> imported natural gas	TJ	**18.934**	**1.000**	**25**	**19.363**	**0**	**0**	**0**	**13.755**	**53.078**
> domestic natural gas	TJ	**9.873**	**0**	**54**	**19.799**	**0**	**787**	**0**	**0**	**30.513**
- LP gas	TJ	0	0	0	0	0	0	0	0	0
- Gas from sewage treatment	TJ	0	0	0	0	0	0	0	0	0
- City gas / other gas	TJ	**164**	**0**	**6.202**	**3.498**	**0**	**93**	**0**	**16.847**	**26.803**
- Blast furnace gas	TJ	**0**	**0**	**0**	**3.420**	**0**	**0**	**0**	**0**	**3.420**
- Special fuels	TJ	**1.009**	**0**	**6.446**	**4.067**	**62**	**966**	**0**	**16.455**	**28.942**

Table 119: Fuel inputs in thermal power stations and district-heat stations (Energy Balance line 18) (new German Länder, 1990)

	Units	Fuels for district-heat production, 1990 EB line 18	District-heat production in large combustion systems of public thermal power stations	District-heat production from gas turbines in public thermal power stations	District-heat production in large combustion systems of power stations in the lignite-mining sector	District-heat production in large combustion systems of industrial power stations of the manufacturing sector and other mining	District-heat production in TA-Luft systems of industrial power stations of the manufacturing sector and other mining	District-heat production in large combustion systems of refinery power stations	District-heat production from public district-heating stations	Of these, district-heat production in large combustion systems	Of these, district-heat production in TA-Luft systems
Annual efficiency	%	81,60%	83,26%	68,11%	79,30%	80,59%	76,97%	85,02%	80,04%		
District-heat production	**TJ**	**227.490**	**109.565**	**167**	**10.874**	**14.253**	**2.659**	**3.952**	**86.021**		
Fuel for district heat	**TJ**	**278.801**	**131.588**	**245**	**13.713**	**17.686**	**3.454**	**4.648**	**107.467**	**33.394**	**74.074**
- Crude lignite	TJ	189.784	87.000	0	10.557	8.770	1.128	1.023	81.306	25.265	56.042
> Lausitz coal field	TJ		*46.503*	*0*	*6.603*	*4.321*	*598*	*0*	*32.522*	*10.106*	*22.417*
>Mitteldeutschland coal field	TJ		*40.497*	*0*	*3.954*	*4.449*	*530*	*1.023*	*48.784*	*15.159*	*33.625*
- Lignite briquettes	TJ	19.569	7.939	0	503	2.462	1.247	0	7.418	2.305	5.113
> Lausitz coal field	TJ		*1.012*	*0*	*333*	*780*	*722*	*0*	*1.738*	*540*	*1.198*
>Mitteldeutschland coal field	TJ		*6.927*	*0*	*170*	*1.682*	*525*	*0*	*5.680*	*1.765*	*3.915*
- Dust / dry coal	TJ	532	0	0	169	0	0	0	363	113	250
> Lausitz coal field	TJ		*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
>Mitteldeutschland coal field	TJ		*0*	*0*	*169*	*0*	*0*	*0*	*363*	*113*	*250*
- Lignite coke	TJ	243	64	0	0	165	11	0	3	1	2
> Low-temperature coke	TJ		*64*	*0*	*0*	*165*	*11*	*0*			
> High-temperature coke	TJ		*0*	*0*	*0*	*0*	*0*	*0*			
- Hard coal	TJ	11.835	1.282	0	2.090	1.503	907	0	6.053	1.881	4.172
- Hard-coal coke	TJ		0	0	0	0	0	0	0	0	0
- Hard-coal briquettes	TJ		0	0	0	0	0	0	0	0	0
- Firewood	TJ		0	0	0	0	0	0	0	0	0
- Heating oil, light	TJ	1.217	0	245	0	0	0	0	972	302	670
- Heating oil, heavy	TJ	16.028	13.820	0	50	504	0	3	1.650	513	1.137
- Diesel fuel	TJ		0	0	0	0	0	0	0	0	0
- Natural gas	TJ	32.724	20.956	0	2	3.891	150	501	7.224	2.245	4.979
> imported natural gas	TJ		*13.268*	*0*	*1*	*1.641*	*0*	*501*			
> Domestic natural gas	TJ		*7.688*	*0*	*1*	*2.250*	*150*	*0*			
- LP gas	TJ		0	0	0	0	0	0	0	0	0
- Gas from sewage treatment	TJ		0	0	0	0	0	0	0	0	0
- Other gases	TJ	5.973	134	0	205	223	0	2.931	2.479	770	1.709
> Burnable gas			0	0	0	0	0	0	0	0	0
> Coking plant / city gas	TJ	5.973	134	0	205	223	0	2.931	2.479	770	1.709
> Refinery gas			0	0	0	0	0	0	0	0	0
- Blast furnace gas	TJ		0	0	0	0	0	0	0	0	0
- Special fuels	TJ	896	391	0	136	167	11	190	0	0	0
> Other petroleum products			0	0	0	0	0	0	0	0	0
> Lignite tar	TJ		0	0	0	0	0	0	0	0	0
> Industrial waste		896	391	0	136	167	11	190	0	0	0

Table 120: Fuel inputs in the transformation sector (auxiliary energy / Energy Balance line 45) (new German Länder, 1990)

	Units	Corrected EB line 45	Heat production in large combustion systems of power stations of the lignite-mining sector	Production of hard-coal coke	Heat production in large combustion systems of refinery power stations	Total (transformation for power stations)	Other process combustion
Industrial heat production	**TJ**		**118.198**		**44.878**	**163.076**	
Fuel for final energy	**TJ**	**224.150**	**149.953**	**3.053**	**54.031**	**207.037**	**17.113**
- Crude lignite	TJ	156.976	138.673	0	18.303	156.976	0
> Lausitz coal field	*TJ*		*88.405*		*0*	*88.405*	
>Mitteldeutschland coal field	*TJ*		*50.268*		*18.303*	*68.571*	
- Lignite briquettes	TJ	306	306	0	0	306	0
> Lausitz coal field	*TJ*		*72*		*0*	*72*	
>Mitteldeutschland coal field	*TJ*		*234*		*0*	*234*	
- Dust / dry coal	TJ	2.677	2.677	0	0	2.677	0
> Lausitz coal field	*TJ*		*0*		*0*	*0*	
>Mitteldeutschland coal field	*TJ*		*2.677*		*0*	*2.677*	
- Lignite coke	TJ	2.520	2.462	0	58	2.520	0
> Low-temperature coke	*TJ*		*2.462*		*58*	*2.520*	
> High-temperature coke	*TJ*		*0*		*0*	*0*	
- Hard coal	TJ	348	348	0	0	348	0
- Hard-coal coke	TJ	60	0	0	0	0	60
- Hard-coal briquettes	TJ	0	0	0	0	0	0
- Firewood	TJ	0	0	0	0	0	0
- Heating oil, light	TJ	0	0	0	0	0	0
- Heating oil, heavy	TJ	5.438	109	0	2.520	2.629	2.809
- Diesel fuel	TJ	0	0	0	0	0	0
- Natural gas	TJ	10.459	0	1.526	8.933	10.459	0
> imported natural gas	*TJ*		*0*		*8.933*	*8.933*	
> Domestic natural gas	*TJ*		*0*		*0*	*0*	
- LP gas	TJ	644	0	0	0	0	644
- Gas from sewage treatment	TJ	0	0	0	0	0	0
- Other gases	TJ	28.311	2.868	1.527	12.599	16.994	11.317
> Burnable gas	TJ	9.598	0	1.527	0	1.527	8.071
> Coking plant / city gas		2.868	2.868	0	0	2.868	0
> Refinery gas		15.845	0	0	12.599	12.599	3.246
- Blast furnace gas	TJ	0	0	0	0	0	0
- Special fuels	TJ	16.410	2.509	0	11.619	14.128	2.282
> Other petroleum products	TJ	13.901	0	0	11.619	11.619	2.282
> Lignite tar		0	0	0	0	0	0
> Industrial waste		2.509	2.509	0	0	2.509	0

Table 121: Final-energy consumption in the "other mining" and manufacturing sectors: process combustion (Energy Balance line 73) (new German Länder, 1990)

Final energy consumption, manufacturing sector, 1990	Units	Corrected EB line 73	Calcium carbide production (process combustion)	Production of iron, steel and malleable cast iron (process combustion)	Glass production (process combustion)	Manufacturing of coarse ceramics (process combustion)	Lime production (process combustion)	Production of non-ferrous heavy metals (process combustion)	Manufacturing of pig iron (process combustion)	Production of Siemens-Martin steel (process combustion)	Sinter production (process combustion)	Manufacturing of rolled steel (process combustion)	Cement production (process combustion)	Sugar manufacturing (process combustion)	Subtotal, process combustion (not including carbide)
				2-9	10-16	17-25	26-37	38-43+80	44-48	49-52	53-55	56-58+81	59-71	72-79	
Industrial heat production	TJ														
Fuel for final energy	TJ	**547.693**		**2.981**	**6.240**	**7.569**	**7.560**	**6.155**	**25.732**	**12.932**	**5.340**	**6.660**	**26.248**	**4.633**	**112.050**
- Crude lignite	TJ	169.921		0	401	2.225	0	0	0	0	0	0	0	0	2.626
> Lausitz coal field	TJ			*0*	*241*	*890*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1.130*
>Mitteldeutschland coal field	TJ			*0*	*160*	*1.335*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1.495*
- Lignite briquettes	TJ	74.324		0	23	3.300	0	1.102	0	0	0	0	0	0	4.425
> Lausitz coal field	TJ														
>Mitteldeutschland coal field	TJ														
- Dust / dry coal	TJ	27.266		0	0	0	0	365	0	0	0	0	14.836	0	15.201
> Lausitz coal field	TJ														
>Mitteldeutschland coal field	TJ														
- Lignite coke	TJ	22.149		0	0	0	2.100	0	0	0	3.348	0	0	0	5.448
> Low-temperature coke	TJ														
> High-temperature coke	TJ														
- Hard coal	TJ	37.442		0	0	22	0	0	0	0	197	0	7.418	3.682	11.318
- Hard-coal coke	TJ	32.260		2.510	0	18	5.250	3.645	16.851	0	1.795	0	0	951	31.021
- Hard-coal briquettes	TJ	0		0	0	0	0	0	0	0	0	0	0	0	0
- Firewood	TJ	0		0	0	0	0	0	0	0	0	0	0	0	0
- Heating oil, light	TJ	2.402		0	141	71	0	0	0	0	0	0	0	0	212
- Heating oil, heavy	TJ	23.070		0	0	0	0	324	3.032	3.816	0	740	0	0	7.912
- Diesel fuel	TJ	10		0	0	0	0	0	0	0	0	0	0	0	0
- Natural gas	TJ	107.410		471	4.332	1.658	210	720	835	8.904	0	4.810	3.994	0	25.934
> imported natural gas	TJ														*0*
> Domestic natural gas	TJ														*0*
- LP gas	TJ	2.395		0	0	0	0	0	0	0	0	0	0	0	0
- Gas from sewage treatment	TJ	0		0	0	0	0	0	0	0	0	0	0	0	0
- Other gases	TJ	28.956		0	1.342	276	0	0	0	212	0	1.110	0	0	2.940
> Burnable gas	TJ	2.803		0	0	0	0	0	0	0	0	0	0	0	0
> Coking plant / city gas		24.762		0	1.342	276	0	0	0	212	0	1.110	0	0	2.940
> Refinery gas		1.392		0	0	0	0	0	0	0	0	0	0	0	0

- Blast furnace gas	TJ	11.417		0	0	0	0	0	5.013	0	0	0	0	0	5.013
- Special fuels	TJ	8.674		0	0	0	0	0	0	0	0	0	0	0	0
> Other petroleum products	TJ	301		0	0	0	0	0	0	0	0	0	0	0	0
> Lignite tar		511		0	0	0	0	0	0	0	0	0	0	0	0
> Industrial waste		7.862		0	0	0	0	0	0	0	0	0	0	0	0

Table 122: Final-energy consumption in the "other mining" and manufacturing sectors: Industrial heat from power stations and heating boilers (Energy Balance line 73) (new German Länder, 1990)

	Units	Corrected EB line 73	Subtotal, process combustion (not including carbide)	Heat production in large combustion systems of public thermal power stations	Heat production in large combustion systems of mine-sector power stations (not including heat for briquetting plants)	Heat production in large combustion systems of industrial power stations of the manufacturing and other mining sectors	Heat production in TA-Luft systems of industrial power stations of the manufacturing and other mining sectors	Heat production in industrial boilers of the manufacturing sector	Of these, heat production in large combustion systems (industrial boilers) of the manufacturing sector	Of these, heat production in TA-Luft systems (industrial boilers) of the manufacturing sector	Other process combustion
Industrial heat production	TJ			3.611	10.335	100.426	10.291				
Fuel for final energy	TJ	547.693	112.050	4.380	13.112	126.687	13.856	160.370	62.305	98.065	117.238
- Crude lignite	TJ	169.921	2.626	4.122	12.126	60.263	6.892	76.000	29.527	46.473	7.892
> Lausitz coal field	TJ		1.130	1.759	7.730	10.294	1.743	30.400	11.811	18.589	3.398
>Mitteldeutschland coal field	TJ		1.495	2.364	4.395	49.969	5.149	45.600	17.716	27.884	4.494
- Lignite briquettes	TJ	74.324	4.425	0	27	8.084	3.640	40.000	15.540	24.460	18.148
> Lausitz coal field	TJ			0	6	3.328	2.021	16.000	6.216	9.784	
>Mitteldeutschland coal field	TJ			0	20	4.756	1.619	24.000	9.324	14.676	
- Dust / dry coal	TJ	27.266	15.201	0	234	0	0	3.500	1.360	2.140	8.331
> Lausitz coal field	TJ			0	0	0	0	1.400	544	856	
>Mitteldeutschland coal field	TJ			0	234	0	0	2.100	816	1.284	
- Lignite coke	TJ	22.149	5.448	0	215	6.199	944	3.500	1.360	2.140	5.843
> Low-temperature coke	TJ			0	215	6.199	944				
> High-temperature coke	TJ			0	0	0	0				
- Hard coal	TJ	37.442	11.318	0	30	10.353	951	13.500	5.245	8.255	1.289
- Hard-coal coke	TJ	32.260	31.021	0	0	0	0		0	0	1.239
- Hard-coal briquettes	TJ	0	0	0	0	0	0		0	0	0
- Firewood	TJ	0	0	0	0	0	0		0	0	0
- Heating oil, light	TJ	2.402	212	0	0	0	0		0	0	2.190
- Heating oil, heavy	TJ	23.070	7.912	113	10	9.070	303	2.000	777	1.223	3.662
- Diesel fuel	TJ	10	0	0	0	0	0		0	0	10
- Natural gas	TJ	107.410	25.934	145	0	26.000	606	11.000	4.274	6.726	43.724
> imported natural gas	TJ		0	2	0	12.887	0				
> Domestic natural gas	TJ		0	143	0	13.113	606				
- LP gas	TJ	2.395	0	0	0	0	0		0	0	2.395
- Gas from sewage treatment	TJ	0	0	0	0	0	0		0	0	0
- Other gases	TJ	28.956	2.940	0	251	1.988	0	7.000	2.720	4.280	16.778
> Burnable gas		2.803	0	0	0	1.988	0		0	0	815
> Coking plant / city gas	TJ	24.762	2.940	0	251	0	0	7.000	2.720	4.280	14.571
> Refinery gas		1.392	0	0	0	0	0		0	0	1.392
- Blast furnace gas	TJ	11.417	5.013	0	0	1.479	0		0	0	4.924
- Special fuels	TJ	8.674	0	0	219	3.252	521	3.870	1.503	2.366	812
> Other petroleum products		301	0	0	0	0	0		0	0	301
> Lignite tar	TJ	511	0	0	0	0	0		0	0	511
> Industrial waste		7.862	0	0	219	3.252	521	3.870	1.503	2.366	0

14.1.2 Energy Industries (1.A.1)

14.1.2.1 Methodological aspects of determination of emission factors (Chapter 3.1.1.2)

This section of the Annex describes the main steps carried out in the research project RENTZ et al (2002) for determination of emission factors. (This description does not apply to the CO_2 emission factors whose determination is described in Annex 2 (Chapter 13.8).

Determination of emission factors requires detailed analysis of all operating plants with regard to technologies used and design-specific emission behaviour. Three superordinated source 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 plants, in terms of percentage shares for various plant types). This procedure thus consists of the following steps:

1. Characterisation of the equipment-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.

2. Analysis of source-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) is divided by source categories that are derived from the national energy balance – cf. Chapter 3.1 – and are not based on the combustion technologies used. The project has defined and analysed the following source 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-heat 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, institutional and commercial users (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, relevant statistics, communications of industry associations (VGB, VDEW, VIK), operator information and technical publications. Furthermore, excerpts of emissions declarations from the year 1996, as provided by some Länder authorities, were also evaluated in the present context.

3. 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 were aggregated to form source-category-specific factors. Finally,

factors for Germany as a whole were formed. The source-category-specific factors are sub-divided in accordance with the categories large combustion systems, TA Luft combustion systems and gas turbines, as well as in accordance with the fuel used. Aggregated emission factors are formed first for the reference year 1995.

4. Projections for 2000 and 2010
   For description of continuing technological development, technology-specific emission factors are again determined. 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. Applicable immission-control laws are used as a framework for updating for the year 2000. It is assumed that the requirements of the amended TA Luft (Technical Instructions on Air Quality Control) and of the EU directive on large combustion systems will be met by the reference year 2010.

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 source-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 70 below.

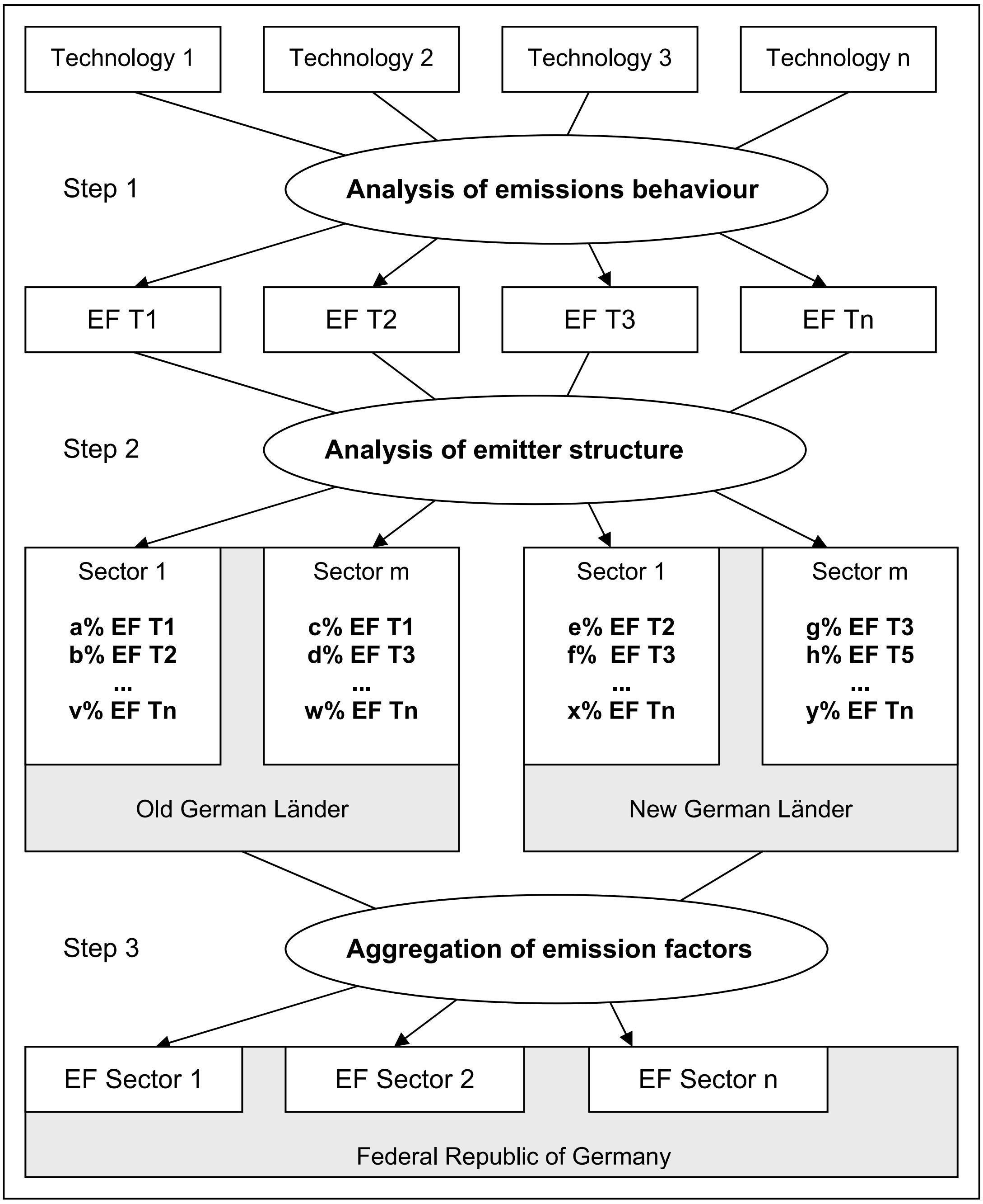


Figure 70: Methods for calculating emission factors

The origins and quality of the data are described in detail in the project report (Rentz et al, 2002). A large part of the data comes from emissions declarations of the Länder Baden-Württemberg, Brandenburg, North Rhine – Westfalia and Thuringia for 1996. The annual pollutant loads listed therein are based, depending on the pollutant concerned, on measurements from continuous monitoring, on individual measurements or on calculation on the basis of 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 pollutants in question. This will then make 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 %[83]. 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 calculation 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 installations subject to abbreviated (K) or complete (V) declarations. For each of the three groups of installations, evaluation and derivation of emission factors is carried out, using the example data from Baden-Württemberg and with separation by measurements and assumptions.

Table 123 provides an overview of the installation types in question and lists the relevant numbers under the 4th BimSchV and the relevant type of declaration required.

Table 123: Installation types pursuant to Annex of 4th BImSchV

Index	**LARGE COMBUSTION PLANTS**	**Type of declaration required**
1 01 1	Power stations ≥ 50 MW for solid, liquid and gaseous fuels	V
1 02A 1	Combustion plants ≥ 50 MW for solid and liquid fuels	V
1 02B 1	Combustion plants ≥ 50 MW for gaseous fuels	V
Index	**TA LUFT INSTALLATIONS**	**Type of declaration required**
1 02A 2	Combustion plants 1 - < 50 MW, solid and liquid fuels (except for heating oil EL)	V
1 02B 2	Combustion plants 5 - < 50 MW heating oil EL	K
1 02C 2	Combustion plants 10 - < 50 MW for natural gas Combustion plants 10 - < 50 MW, except for natural gas installations	K V
1 03 1	Combustion plants > 1 MW, other fuels	V
Index	**GAS-TURBINE INSTALLATIONS**	**Type of declaration required**
1 05 1	Gas turbines ≥ 50 MW for natural gas Gas turbines ≥ 50 MW, except for natural gas installations	K V
1 05 2	Gas turbines < 50 MW for natural gas Gas turbines < 50 MW, except for natural gas installations	K V

In the analyses, emissions data is differentiated by combustion technologies. Table 124 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.

83 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. This value is termed a *quantile*: or, where percentage shares are used, as a *percentile*:). The best-known percentile that separates the lower half of all values from the upper half is the 50% percentile, the so-called *median*. The 25 and 75% 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).

Table 124: Classification of sources by type of combustion system

Technology	
Type	**Type meaning**
110	Combustion plants for solid fuels / waste
111	Filled-shaft combustion plants
112	Combustion plants with belt feed
113	Combustion plants with pneumatic feed
114	Combustion plants with bottom feed
115	Combustion plant with mechanically moving grid
116	Dust combustion with dry-ash removal
117	Dust combustion with wet-ash removal
118	Fluidised-bed combustion
120	Combustion systems for liquid fuels / waste
121	With vaporizer burner
122	With pressurised atomiser burner
123	With steam-atomiser burner
124	With rotating atomiser burner
125	With air-atomiser burner
130	Combustion plants for gaseous fuels / waste
131	With atmospheric gas burner
132	With gas-blower burner
141	Multiple-fuel combustion plants
142	Mixed combustion plants
815	Gas turbines

14.1.2.2 Methods for determining uncertainties of emission factors (Chapter 3.1.1.2)

This section of the Annex describes the main steps carried out in the research project RENTZ et al (2002) for determining the uncertainties of emission factors (except for those of CO_2 emission factors).

The guide on describing uncertainties in measurements (Leitfaden zur Angabe der Unsicherheit beim Messen; DIN, 1995: DIN 1319) recommends the following systematic approach for cases in which not enough observations have been carried out to yield a meaningful result, via calculation of averages and standard error:

On the basis of the available information, limits (upper and lower limit a_+ and a_-) are determined for the value to be determined, X_i. If no special findings regarding possible values of X_i within this range are available, then it must be assumed that all possible values have the same probability, an assumption that corresponds to a uniform or square distribution of possible values. Then, the expected value x_i lies in the middle of the estimated range. The following relationship holds for the pertinent variation:

$$u^2(x_i) = (a_+ - a_-)^2 / 12 \qquad \text{(A1)}$$

For actual physical reasons, values in the vicinity of the middle of the range often have a higher probability than values near the limits. This leads to the assumption of a symmetric trapezoidal distribution, with a base line of length a+ - a- (= 2a) and a top line of length 2aβ with 0 < β < 1. For β = 0, a triangular distribution results. The following relationship holds for the pertinent variation:

$$u^2(x_i) = a^2 (1 + \beta^2) / 6$$

The estimated standard error u is thus calculated as the positive square root of u^2.

The standard error of approximated, normally distributed values can also be roughly estimated via the interdecile range (Sachs 1992). The following approximation holds:

$$u \approx 0{,}39\ (DZ_9 - DZ_1), \qquad (A2)$$

where DZ_9 and DZ_1 stand for the 90th and 10th percentiles, respectively.

The IPCC guidelines recommend that the uncertainty be given via the 95% confidence interval, which can be approximated as double the value of the standard error. To obtain a relative error, one determines the share of 2u in the value X_i. Via multiplicative linking of various independent values that are subject to uncertainties, one can calculate the *combined standard error* as the positive square root of the sum of variations. This approximation holds, pursuant to IPCC-GPG (2000), as long as the relative standard error of any component does not exceed a value of 30 %.

$$u_{total} = \sqrt{u_1^2 + u_2^2 + ... + u_n^2} \qquad (A3)$$

Quantification of the uncertainties of emission factors for combustion plants

For derivation of emission factors, various sets of data, of varying extensiveness depending on pollutant and source category, are available for Germany; this data can be used as a basis for determining the pertinent uncertainties. The data is classified in keeping with the main groups defined for the report – large combustion plants, combustion plants under the TA Luft and gas turbines. First, the uncertainty of the relevant technology-specific factors is evaluated. Then, the uncertainty must be taken into account that results from aggregation of these factors for the various source categories used for the emissions calculation. Finally, the uncertainty resulting from extrapolation of the emission factors for 2000 and 2010 must be taken into account.

The relationships A1 and A2 above, for determination of the standard error and 2u, respectively, were reviewed via examples for which a comparatively large number of individual data items is available (30 – 70) and thus the standard error of the relevant random sample can be calculated.

Example: NO_X emissions from large combustion plants (lignite)

a) New German Länder

Random sample: n = 77;

DZ_1: 68.4 g/GJ; quartile 25%: 113.5 g/GJ; median: 134 g/GJ; mean value: 135.6 g/GJ;

quartile 75%: 154.5 g/GJ; DZ_9: 187.7 g/GJ;

Calculated standard error u = 45.3 g/GJ (relative error of 67.6 %)

Estimation of u pursuant to A1: 46.9 g/GJ (69.9 %)

Estimation of u pursuant to A2: 46.4 g/GJ (69.2 %)

b) Old German Länder

Random sample: n = 30;

DZ_1: 67.5 g/GJ; quartile 25%: 70.6 g/GJ; median: 74 g/GJ; mean value: 72.6 g/GJ;

quartile 75%: 75.9 g/GJ; DZ_9: 77.7 g/GJ;

Calculated standard error u = 6.1 g/GJ (relative error of 16.6 %)

Estimation of u pursuant to A1: 5.3 g/GJ (14.3 %)

Estimation of u pursuant to A2: 4 g/GJ (10.8 %)

The examples considered show that, especially for smaller random samples, estimation with A1 yields better agreement with the calculated standard error than does estimation with A2. The quantiles, the upper and lower limits, were set at 5 % and 95 %. With even smaller random samples, conventional calculation methods produce larger standard errors. Determination of emission factors, in contrast to determination of the correctness of measurements, involves assessing the robustness of results. In actual emissions calculation, some compensation can occur through simultaneous overestimation and underestimation within the totality of all sources. For example, in example a), the individual factors are widely scattered, while the higher emission factors account for smaller shares of the relevant activities. If the random sample is considered as a complete survey, then a factor of 119 g/GJ results for the observed emission, which corresponds to a 15 g/GJ deviation from the median.

The robustness of the emissions calculation can be characterised by noting that consideration of the entire range of factors is likely to lead to overestimation of the actual uncertainty. The upper and lower boundaries of the range are thus estimated with the upper and lower quartiles. In the case of a), this produces a relative error of 18 %. This also corresponds to the order of magnitude estimated, in other studies, for the uncertainty of NO_X emission factors from energy conversion.

To evaluate the uncertainty of the proposed emission factors, the upper (a_+) and lower (a_-) quartiles are determined, on the basis of the surveyed individual data, and then the standard error is estimated in accordance with equation (A1). Similarly, the relative uncertainty is calculated as $2u/X_i$. This procedure is used first to determine the uncertainties of the technology-specific factors. Then, these uncertainties are linked with the uncertainty resulting from aggregation to form source-category-specific factors.

In aggregation of technology-specific factors to form source-category-specific factors, the former are weighted and added in accordance with their relative contributions to the source-category structure. As a simplification, such weighting is also carried out in linking of the relative errors.

14.1.2.3 Methane emission factors in the research project RENTZ et al, 2002

The following Table 125 summarises the emission factors shown in Tables 3, 4 and 5 of Annex E of the research project RENTZ et al (2002):

Table 125: Methane emission factors for combustion systems < 50 MW thermal output and for gas turbines, pursuant to RENTZ et al, 2002

Plant type	Fuel	German Länder	CH_4 EF [kg/TJ]
Combustion systems < 50 MW thermal output	Hard coal	ABL	3,4
		NBL	3,3
	Hard-coal coke	ABL/NBL	19
	Lignite	NBL, Lausatian district	269
		NBL, Central German district	184
	Heating oil EL	ABL	0,02
	Natural gas	ABL/NBL	0,02
Gas turbines	Heating oil EL	D	0,5
	Natural gas	D	2

ABL Old German Länder
NBL New German Länder

D Total for Federal Republic of Germany

14.1.3 Transport (1.A.3)

14.1.3.1 Transport – Civil aviation (1.A.3a)

14.1.3.2 Derivation of activity rates for road transport (1.A.3b)

14.1.3.2.1 Cross-check with 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 is shown in Table 126 below.

Table 126: Energy balances, 1990-2004

Year	Region	Line	Petrol	Petroleum	Diesel fuel	LP gas	Biodiesel
Energy input in road transports, pursuant to energy balances 90-99 (last revision: 12/2002), in TJ							
1990	ABL	75	1159942	0	657443	138	0
1990	NBL	75	170537	0	78477	0	0
1991	ABL	75	1156589	0	700405	137	0
1991	NBL	75	175696	0	84769	0	0
1992	ABL	75	1157939	0	740248	229	0
1992	NBL	75	186190	0	113254	0	0
1993	ABL	75	1158636	473	777146	184	0
1993	NBL	75	191981	0	130641	0	0
1994	ABL	75	1082653	559	787800	184	0
1994	NBL	75	193984	0	144260	0	0
1995	D	62	1299982	610	964013	138	1504
1996	D	62	1299879	638	964580	115	2046
1997	D	62	1297487	357	979586	106	3652
1998	D	62	1300463	637	1022794	106	4081
1999	D	62	1300602	637	1097036	100	5370
2000	D	62	1237055	600	1108726	100	9306
2001	D	62	1199318	600	1098488	100	13032
Provisional figures pursuant to evaluation tables*							
2002	D	62	1166000	600	1105790	100	20447
2003	D	62	1109000	600	1078382	100	24199
2004	D	62	1074121	600	1120139	100	32000
Sources: Evaluation tables, last revision 09/2004, Data of the Working Group on renewable-energy statistics (Arbeitsgemeinschaft Erneuerbare Energien Statistik) and NWV-Mineralölwirtschaftszahlen 2004 (petroleum statistics) (MWV 2005); ABL = old German Länder; NBL = new German Länder; D = Germany.							

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 traffic, 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 average 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 of the Working Group on Energy Balances (AGEB) are used (cf. Table 127).

Table 127: Net calorific values for petrol and diesel fuel

Year	Petrol	Diesel fuel
1990-1992	43,543 MJ/kg	42,704 MJ/kg
As of 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 petrol is derived from the calculated petrol consumption for all vehicle categories and petrol sales pursuant to the Energy Balance.
- The correction factor for petrol is then also used to bring fuel consumption of vehicles with diesel engines, including automobiles and other vehicles <= 3.5 t (light duty vehicles (LNF), and of motor homes and motorcycles (MZR)), in 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 busses.
- The correction factor for heavy duty vehicles and busses 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.

Table 128 below summarises the correction factors used.

Table 128: Correction factors for adjustment to the Energy Balance

Year	Region	Petrol	Diesel fuel	
		Automobiles, light duty vehicles, motorcycles	Automobiles, light duty vehicles, motorcycles	Other
1990	ABL	1,016	1,016	1,147
1990	NBL	1,024	1,024	1,588
1991	ABL	1,017	1,017	1,102
1991	NBL	1,036	1,036	1,097
1992	ABL	1,025	1,025	1,176
1992	NBL	0,989	0,989	1,253
1993	ABL	1,029	1,029	1,282
1993	NBL	0,974	0,974	1,186
1994	ABL	0,970	0,970	1,185
1994	NBL	0,970	0,970	1,185
1995	D	0,982	0,982	1,205
1996	D	0,987	0,987	1,182
1997	D	0,989	0,989	1,179
1998	D	0,987	0,987	1,242
1999	D	0,994	0,994	1,301
2000	D	0,969	0,969	1,381
2001	D	0,963	0,963	1,251
2002	D	0,961	0,961	1,166
2003	D	0,952	0,952	1,091
2004	D	0,965	0,965	1,029
Remarks: 1994 correction factors for ABL (old German Länder) and NBL (new German Länder) as for D as a whole				

14.1.3.2.2 Allocation of biodiesel, petroleum and LP gas to the structural elements

In the Energy Balance, biodiesel, petroleum and LP gas are listed in the transport sector; for this reason, they have not been included in TREMOD, to date, as separate categories. For purposes of importing into CSE, the results for these fuels are thus derived additionally. To this end, the energy consumption, pursuant to the Energy Balance, is allocated to the relevant structural elements in keeping with the specifications of the Federal Environmental Agency (for abbreviations, cf. Table 15):

- **Biodiesel** is allocated to all structural elements with diesel engines, in keeping with their percentage shares of consumption of conventional diesel fuel.
- **Petroleum** is allocated to busses on roads outside of municipalities – and, thus, to the structural elements SV BUS KOAO and SV BUS MTAO – in keeping with their percentage shares of consumption of conventional diesel fuel
- **LP gas** is allocated to conventional automobiles, with petrol engines, on municipal roads (structural element SV PKWO KOIO).

14.1.3.2.3 Activity rate for evaporation

The activity rate for evaporation emissions is set as total petrol consumption, on municipal roads, pursuant to TREMOD; the corresponding figure for mopeds is the total consumption. The values corrected for the Energy Balance are used.

14.1.3.3 Derivation of emission factors

14.1.3.3.1 Emission factors from TREMOD

In the CSE, emission factors for the "engines" ("Antrieb") category are listed in kg/TJ, while those for the "Evaporation" category are given in kg/t. For the subtances "petrol" and "diesel fuel", these values can be derived from TREMOD for all structural elements. To this end, emissions (in tonnes) and energy consumption (in TJ; converted from the results "energy consumption in t", using the net calorific values pursuant to Table 127) are derived from the TREMOD results and allocated to the relevant structural elements. The emission factor for each structural element then results as the quotient of emissions, in tonnes per structural element, divided by the energy consumption, per structural element, in TJ. A similar procedure is used to obtain the emission factors for evaporation (evaporation emissions, in kg / consumption on municipal roads, in t).

For purposes of this derivation, TREMOD results without correction to the Energy Balance are used, since such correction is already contained in the activity rates for the CSE. Use of the corrected values (emissions and energy consumption) leads to the same results, however, since the correction factor cancels out in calculation of mean emission factors (emissions corrected / energy corrected = emissions uncorrected / energy uncorrected).

14.1.3.3.2 Emission factors for biodiesel, petroleum and LP gas

For all structural elements, the emission factors for biodiesel and petroleum, in keeping with the Federal Environmental Agency's specifications, are set to the same values as those for conventional diesel fuel. Exceptions:

- The CO_2 emission factor for biodiesel is set to "0"
- The SO_2 emission factor for petroleum: in those years in which diesel fuel has a higher value, this factor is set to 24 kg/TJ. In all other years, the lower value for diesel fuel is used.

The emission factors for automobiles that run on LP gas are set as follows, in keeping with the Federal Environmental Agency's specifications:

Table 129: Emission factors for automobiles that run on LP gas

Gas	Technology	Structural element	EB line	Units	1995-2001
CH_4	Automobile	SV PKWO KOIO	EB line 62	kg/TJ	3
CO	Automobile	SV PKWO KOIO	EB line 62	kg/TJ	350
CO_2	Automobile	SV PKWO KOIO	EB line 62	kg/TJ	65.000,00
N_2O	Automobile	SV PKWO KOIO	EB line 62	kg/TJ	1,7
NH_3	Automobile	SV PKWO KOIO	EB line 62	kg/TJ	0,5
NMVOC	Automobile	SV PKWO KOIO	EB line 62	kg/TJ	157
NO_X	Automobile	SV PKWO KOIO	EB line 62	kg/TJ	975
SO_2	Automobile	SV PKWO KOIO	EB line 62	kg/TJ	1,7

14.1.3.4 Expansion to include natural gas as a fuel

TREMOD updating includes the option of listing natural gas as a fuel, if the Working Group on Energy Balances (AGEB) lists natural gas as a transport fuel in future. In the present interface, this is possible only if the allocation criteria are precisely defined, in a manner similar to that used for biodiesel, natural gas and petroleum:

- Listing of the affected structural elements and their respective percentage shares of consumption
- Listing of emission factors for the relevant structural elements

Furthermore, general data tables could now be defined into which these figures could be explicitly entered. The minimum requirements are listed in the following tables (Table 130 and Table 131):

Table 130: Entry structure for natural gas: Structural element's percentage share of energy consumption

Material	Structural element	Share/year
Natural gas	e.g. SV BUS MTIO	60%
Natural gas	...	...
Natural gas	Total	100%

Table 131: Entry structure for natural gas: Emission factors

Gas	Structural element	Units	Values / reference year
CH_4	e.g. SV BUS MTIO	kg/TJ	
CO	e.g. SV BUS MTIO	kg/TJ	
CO_2	e.g. SV BUS MTIO	kg/TJ	
N_2O	e.g. SV BUS MTIO	kg/TJ	
NH_3	e.g. SV BUS MTIO	kg/TJ	
NMVOC	e.g. SV BUS MTIO	kg/TJ	
NO_X	e.g. SV BUS MTIO	kg/TJ	
SO_2	e.g. SV BUS MTIO	kg/TJ	

Alternatively, the percentage shares for structural elements can be given in a form similar to that used for existing structures (as is done for petroleum and biodiesel). To this end, a suitable calculation rule would have to be defined and developed (for example, breakdown of natural gas by the vehicle categories BUS, LNF and SNF on municipal roads, in keeping with the various categories' shares of diesel-fuel consumption). This approach is more complex, and it is more difficult to adapt to changed allocation rules, but it offers the advantage that the percentage shares do not have to be defined explicitly, for each year, in a table.

Since it is difficult to specify a relevant calculation rule at present, natural-gas tables should be added to the current interface; these tables could then be filled as necessary. Such tables will also be integrated into the final version if necessary. In future, an attempt should be made to integrate the fuels biodiesel, petroleum, LP gas and natural gas directly within TREMOD, however.

14.1.3.5 Derivation of data for western and eastern Germany, 1994

TREMOD distinguishes between old and new German Länder only until 1993. Since CSE also requires such differentiation for 1994, a relevant breakdown must be made using simplifying assumptions. The parameters include:

- The sum total of activity rates for engines (Antrieb) must correspond to the relevant Energy Balance values (in each case, old and new German Länder).
- In the overall result, emissions resulting from linking activity rates with emission factors must correspond to the TREMOD results for Germany.

- With these parameters, the present study can carry out a relevant breakdown only under the following assumptions:
- The emission factors for old and new German Länder are set, for all structural elements, to the relevant values for all of Germany in 1994.
- The structural elements' percentage shares of the activity rates, for each fuel, are considered to be the same in each case for the old and new German Länder, and they correspond to the relevant values for all of Germany in 1994.

With these assumptions, the aforementioned conditions are met. A third condition is not met, however: the plausibility of emissions results in the time series, in each case, for the old/new German Länder. For this condition to be fulfilled, the year 1994 should be remodelled in TREMOD; this should be done via separate derivation of vehicle stocks and mileages for the old and new German Länder, followed by recalculation of emissions on the basis of this data.

14.1.4 Oil and natural gas (1.B.2)

14.1.5 Aviation and Marine (1.BU.1/1.BU.2)

14.2 Other detailed methodological descriptions for the source category "Industrial processes" (2)

14.2.1 Mineral products (2.A)

14.2.2 Chemical industry (2.B)

14.2.2.1 Chemical industry: Nitric acid production (2.B.2)

14.2.2.1.1 IPCC requirements pertaining to emissions calculation

Nitrous oxide emissions E_{N2O} [kg] are calculated from the activity rate [t HNO_3], a pertinent emission factor [kg N_2O/t HNO_3] and, if applicable, the efficiency and relative operating time of a system for N_2O emissions reduction, with:

E_{N2O} *= AR x EF x (1 – N_2O-reduction factor x rel. operating time of reduction system)*

The relative operating time of the N_2O-reduction system was included so that down time could be taken into account. Alternatively, the entire last term can be included within the EF.

Since EF depend strongly on plant type and on N_2O-reduction method used, emissions for main source groups should be determined at the plant level. To this end, the activity rate and emission factor must be determined in each case, or emissions must be measured in each plant. If the operator provides the data, it must be ensured that adequate QC/QA measures are carried out.

The EF listed in the IPCC Guidance (2000: Tab. 3.8) range from less than 2 to 19 kg N_2O/t HNO_3, and they depend strongly on plant age, plant design and type of NO_x-reduction equipment used. If production data, but no emissions measurements, are available for each plant type, adequate IPCC default values should be used. Activity rates that have been aggregated across different plant types should be used only if more detailed data cannot be obtained.

In determination of plant-specific EF, regular measurements, carried out at different types, are normally able to prevent systematic errors and to provide the desired degree of precision. Normally, it is a good practice to carry out measurements and analyses whenever significant changes in a plant's processes occur that affect the rate at which N_2O is produced. In addition, such measurements should serve the purpose of ensuring that the operational conditions have remained constant. Plant operators should be queried annually regarding their reduction technologies, and they should confirm that they have indeed used the technologies they have described. For precise determination of emissions rates and efficiencies of N_2O-reduction systems, measurements of both controlled and uncontrolled waste-gas flows must be carried out. Where measurement data is available only for controlled waste gases, it is good practice to base emissions figures on this data. In such cases, estimates of the efficiency of N_2O-reduction systems should be used only for information purposes and should not be used in emissions calculations.

For European systems ("dual pressure, double absorption"), 8-10 kg N_2O/t is proposed as the default value; for older systems dating from before 1975, 10-19 kg N_2O/t is proposed. Non-selective catalytic reduction (NSCR) for reducing NO_x emissions also destroys N_2O, and the relevant reduction rate is given as 80-90%. Other methods for NO_x reduction either have no impact on N_2O emissions or can even increase them.

14.2.3 Metal production (2.C)

14.2.3.1 Metal production: Iron and steel production (2.C.1, 1.A.2.a)

14.2.3.1.1 Determination of total emissions

The total emissions for the iron and steel industry are determined as the sum of emissions from reducing agents and fuels used by the sector. In the process, steel production is considered in a one step. Pig-iron production is not balanced separately (cf. also Chapters 3.1.4 and 4.3.1).

In terms of methods, this procedure for determining total emissions corresponds to that previously used for determining iron and steel industry emissions as reported under 1.A.2.

14.2.3.1.2 Determination of process-related emissions

In the interest of maintaining congruence with data of the German Emissions Trading Authority (DEHSt), in sector 2.C.1, "Iron and steel industry", process-related CO_2 emissions from steel production are calculated, as in the Ordinance on allocations for emissions trading (Zuteilungsverordnung für den Emissionshandel; ZuV on the basis of the Greenhouse Gases Emissions Trading Act (TEHG)) with the help of the factor for an ideal blast-furnace process (SCHOLZ, 2003).

An emission factor of 1.307 t CO_2 / t product results. This factor is obtained by multiplying the factor for the ideal blast-furnace process, 356.5 kg C per tonne of pig iron, by 44/12 (the CO_2-to-C mass relationship).

Emissions from reducing agents that are in addition to the thusly calculated quantity of CO_2 are added to the energy-related emissions; cf. below.

Emissions from electrode combustion and limestone inputs are determined separately and then, in a final step, are added to the other process-related emissions.

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 processing of iron ores (sintering plants) and in pig-iron production in blast furnaces. On the other hand, (burnt) steel-works lime (CaO) is used – inter alia, as a slag former – in actual refining of raw steel in oxygen-steel or electric-steel processes. Limestone inputs in sinter and pig-iron production are published annually in iron and steel sector statistics (DESTATIS FS 4, R 8.1). These statistics provide the basis for the limestone inputs in sinter and pig-iron production shown in the following table.

Table 132: Limestone inputs in sinter and pig-iron production

Limestone inputs [kT]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Sinter	4.681	4.566	4.152	3.988	4.281	4.426	4.273	4.507	4.526	4.190	4.381	4.240	4.091	4.202	4.371
Pig iron	705	726	669	632	701	703	649	725	707	654	723	684	689	691	703

Source: Calculations from the "limestone balance" project ("Kalksteinbilanz"; UBA 2006, FKZ 20541217/02)

Multiplying the activity rates for limestone inputs by the IPCC default value for limestone produces the following CO_2-emissions figures.

Table 133: CO_2 emissions from limestone inputs in sinter and pig-iron production

[Gg CO_2]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Sinter and pig iron	932	991	1050	1110	1170	1229	1288	1348	1407	1467	1526	1585	1645	1704	1764

Source: Calculations from the "limestone balance" project ("Kalksteinbilanz"; UBA 2006, FKZ 20541217/02)

14.2.3.1.3 Determination of energy-related emissions

Energy-related CO_2 emissions are obtained as the difference between total emissions and process-related emissions (not including emissions from electrode combustion and limestone inputs).

The pertinent difference is formed in 2 steps.

Firstly, the emission factors for all of the reducing agents used in blast furnaces are set to zero on the energy side.

In a second step, a corrective time series in the CSE is used to add non-process-related blast-furnace emissions to energy-related emissions under 1.A.2.a. For this operation, fuel-specific allocation is hardly feasible, and it would not enhance accuracy in any case.

All natural-gas inputs in blast furnaces (wind heaters) are reported together with energy-related emissions.

All emission factors for inputs of blast-furnace gas (also in power stations and in sinter production) are set to zero, since the relevant emissions were already taken into account in connection with production of blast-furnace gas in blast furnaces (process-related emissions in 2.C.1). (In the 2005 National Inventory Report, CO_2 emissions from blast-furnace gas in the iron and steel industry were reported in sector 1.A.2.)

This approach ensures that no double-counting takes place.

Table 134: Allocation of fossil CO_2 emissions in the iron and steel industry to process-related and energy-related emissions

	Sintering plant/ Sinter production	Blast furnace/ Pig iron production	Hot rolling mill/ Rolled steel production	Electric-steel mill/ Production of electric steel	Iron, steel and malleable foundries
Hard coal	E	E/P*			
Hard-coal coke		E/P*			E
Lignite briquettes	E				
Lignite coke	E				
Heating oil - heavy		E/P*			
Other petroleum products		E/P*			
Coke breeze (classified under hard-coal coke)	E				
Natural gas	E	E**	E		E
Coking gas	E				
Blast furnace gas	P	E/P*			
Recycled plastics		E/P*			
Electrode combustion				P	

E: energy-related (emissions reported in 1.A.2);
P: process-related (emissions reported in 2.C.1)
Note: No significant fuel use occurs in oxygen steel plants. Therefore, this section does not include a separate category for such plants.
*) Breakdown via the factor for the ideal blast-furnace process; see text.
**) Natural-gas use in blast-furnace wind heaters creates no process-related CO_2 emissions; it only generates energy-related CO_2 emissions

14.2.3.1.4 Secondary fuels

In the iron and steel industry, secondary fuels are used as substitute reducing agents, in place of coke, only in pig-iron production via the blast-furnace process. To date, these materials have not yet been included in national statistics and the Energy Balance. Relevant production figures and fuel-use amounts have been taken from statistics of the Wirtschaftsvereinigung Stahl steel-industry association. The procedure used to compile activity rates oriented to the territory of Germany, for the period as of 1995, is described in the final report of the research project "Inputs of secondary fuels" ("Einsatz von Sekundärbrennstoffen"; UBA 2005b, FKZ 20442203/02). The relevant types, amounts, energy inputs and CO_2 emission factors were provided by the Wirtschaftsvereinigung Stahl steel-industry association.

Table 135: Secondary-fuel inputs in blast furnaces: CO_2 emission factors and their biogenic components

Secondary fuel (Designation in the CSE)	CO_2 emission factor [kg/ TJ]	Biogenic mass fraction [%]
Animal fat	71.380	100
Recycled plastics	74.630	0

At the same time, emissions from use of secondary fuels in the blast-furnace process are not reported under 1.A.2.a.; instead, they are subsumed within process-related emissions in 2.C.1.

14.2.4 Other production (2.D)

14.2.4.1 Pulp and paper (2.D.1)

The fibre for paper production is produced, via chemical or mechanical processes, either from fresh fibre or from processed recycled paper. A distinction is made between integrated and non-integrated pulp and paper mills. Non-integrated pulp mills (that produce pulp for the market) solely produce pulp for sale on the open market. On the other hand, integrated mills produce both pulp and paper, at integrated sites. A paper mill can either produce paper from fibre material produced at other locations or be integrated within complete pulping processes set up at one site.

Sulphate pulp mills normally operate in both integrated and non-integrated modes, whereas sulphite pulp mills are normally only integrated – i.e. part of paper-production chains. In most cases, paper production includes both mechanical pulping and used-paper processing, although in some cases such processes are carried out separately.

14.2.4.1.1 Fibre production processes

Sulphate process

The sulphate process is the world's most common pulping process, since it yields higher pulp strengths and can be used with all types of wood. In the two German plants, carbonate is extracted from the circulation of lye via bonding with calcium (causticising) and then, in a separate lime oven, is burned to burnt lime, a process that releases CO_2; the burnt lime is then reused for causticising. Pursuant to the *IPCC Good Practice Guidelines*, CO_2 released from $CaCO_3$ is assigned an emission factor of "0", since all of its carbon comes from pulped wood. Calcium loss from the cycle is compensated for solely via addition of burnt lime and thus, for the present purposes, also does not lead to report-relevant CO_2 emissions (the CO_2 released in production of burnt lime is already included in the figures for the lime industry (CRF 2.A.2)).

This process produces atmospheric emissions in lye recovery (boilers), in bark combustion, from lime ovens, in wood-chip storage, in pulp digestion, in pulp washing, in bleaching, in bleach-chemical processing, in evaporation, in sorting and washing, in processing of circulating water and in operation of various types of tanks. Such emissions include fugitive emissions that occur at various processing points – primarily in lye-recovery boilers, lime ovens and auxiliary boilers. The main components of emissions include nitrogen oxides, sulphur-containing compounds, such as sulphur dioxide, and foul-smelling reduced sulphur compounds.

The two German sulphate-pulping plants are fitted with a system for post-incineration of foul-smelling sulphur compounds and with systems for NO_x-reduced combustion in lye-recovery boilers (>20 % NO_x reduction).[84]

Other types of emissions-reduction equipment are not yet being used in Germany:

- *Scrubbers* downstream from recovery boilers (>85 % SO_2 reduction)
- SNCR equipment for NO_x reduction downstream from the auxiliary boiler (>30 % NO_x reduction)
- SNCR equipment for NO_x reduction downstream from the recovery boiler (>30 % NO_x reduction)

[84] Figures of the Verband Deutscher Papierfabriken (VDP; German paper producers' association), September 2004

- NO_x-reduction systems for combustion in auxiliary boilers (>20 % NO_x reduction) [31]

Sulphite process

Sulphite pulp is produced in 4 of 6 systems in Germany. In such plants, pulping is carried out with various chemicals. The sulphate process and the sulphite process have numerous similarities, including similarities with regard to possibilities for using various internal and external measures to reduce emissions. From the standpoint of environmental protection, the main differences between the two pulp-production processes have to do with chemical aspects of the boiling process, with aspects of preparation and post-processing of chemicals and with bleaching intensity – bleaching in sulphite plants is less intensive, since sulphite pulp is whiter than sulphate pulp.

Atmospheric emissions occur especially in lye recovery (boilers) and in bark combustion. Waste-gas emissions with less-concentrated SO_2 are released in washing and sorting processes, and they are released by ventilation shafts of evaporators and by various tanks. Such emissions escape – in part, as fugitive emissions – at various points of the process. They consist primarily of sulphur dioxide, nitrogen oxides and dust.

A number of measures are available for reducing consumption of fresh steam and electrical energy and for increasing plant-internal generation of steam and electricity. Sulphite pulp mills can generate their own heat and electricity by using the thermal energy in concentrated lye, bark and waste wood. Integrated plants require additional amounts of steam and electricity, however; these additional amounts can be generated in either in on-site facilities or at off-site locations. Integrated sulphite pulp and paper mills consume 18 - 24 GJ of process heat, and 1.2 - 1.5 MWh of electrical energy, per tonne of pulp.

All four sulphite pulping plants in Germany are operated with SO_2 scrubbers fitted downstream from recovery boilers (>98 % SO_2 reduction). One plant is fitted with equipment for NO_x-reduced combustion in recovery and auxiliary boilers (total of >40 % NO_x reduction) [31].

No other types of emissions-reduction equipment are yet being used in Germany:

- SNCR equipment for NO_x reduction downstream from the auxiliary boiler (>30 % NO_x reduction)
- SNCR equipment for NO_x reduction downstream from the recovery boiler (>30 % NO_x reduction) [31]

Wood pulp

Wood pulp is produced in 9 plants in Germany. In mechanical pulping, wood fibres are separated from each other via mechanical energy applied to the wood matrix. This process is designed to conserve most of the lignin in the wood, in order to maximise yields while ensuring that the pulp has adequate strength and whiteness. Two main processes are differentiated:

- The wood-grinding process, in which pieces of wood are are wettened and pressed against a rotating grinder, and
- The *refiner* process, in which wood chips are broken down into fibres in disk refiners.

Wood-pulp properties can be influenced by increasing the process temperature and, in the case of the *refiner* process, by chemical pre-treatment of the wood chips. The pulping process in which wood is chemically pre-softened and then broken down into fibres, under pressure, is known as *chemical-thermal-mechanical pulping* (CTMP).

In most cases, the waste-gas emissions consist of emissions from heat and energy generation in auxiliary boilers and of emissions of volatile organic carbon (VOC). VOC emissions occur in storage of wood chips and in removal of air from containers for washing wood chips and from other types of containers. They also occur in connection with condensates that are produced in recovery of steam from *refiners* and contaminated with volatile wood components. Some of these emissions are released as fugitive emissions, from various parts of mills.

The best available technologies for reducing waste-gas emissions include effective recovery of heat from refiners and reducing VOC emissions from contaminated steam. Along with VOC emissions, mechanical pulping produces waste-gas emissions from on-site energy generation (i.e. non-process-related emissions). Heat and electricity are generated through combustion of various fossil fuels and wood residues (the latter a renewable resource). The best available technologies for auxiliary boilers are described below.

Recycled fibre

In general, processes that use recycled fibres (processes for processing used paper) can be divided into two main categories:

- Processes that use solely mechanical cleaning, i.e. processes that use no de-inking. Such processes are used for production of test liners, fluting, carton and cardboard;
- Processes that use mechanical and chemical technologies, i.e. that include de-inking. Such processes are used for production of newsprint, tissue, printing and copier paper, magazine papers (SC/LWC) and for some types of carton and commercial DIP (de-inked recycled paper).

The raw materials for paper production from recycled fibre include recycled paper (main component), water, chemical additives and energy in the form of steam and electricity. Waste-gas emissions occur primarily in energy generation through fossil-fuel combustion, in power stations.

Waste-gas emissions from mills that process recycled paper occur primarily in systems for heat production; in some cases, they are also produced by combined heat/power generation (CHP) systems. For this reason, energy efficiency is closely linked to reductions of waste-gas emissions. The energy-generation systems in such mills normally use standard boilers, and thus they may be considered truly similar to all other such power plants. The following measures are considered the best available techniques for reducing energy consumption and emissions into the atmosphere: heat-power cogeneration, modernisation of existing boilers and retrofits (in connection swith replacement investments) with more energy-efficient systems.

Energy-efficient mills for processing recycled paper consume process heat and electrical energy on the following scales:

- Integrated mills that process recycled paper, without de-inking (for example, for production of test liners and fluting):
6 – 6.5 GJ/t process heat and
0.7 – 0.8 MWh/t electrical energy;
- Integrated mills for tissue production, with DIP systems:
7 -12 GJ/t process heat and
1 – 1.4 MWh/t electrical energy;

- Integrated mills for production of newprint, and integrated mills for production of printing and writing paper, and including DIP systems:
  4 – 6.5 GJ/t process heat and
- 1 – 1.5 MWh/t electrical energy.

14.2.4.1.2 Paper and carton production

Paper is made from fibre materials, water and chemical additives. The entire paper-making process consumes large amounts of energy. Electricity is required primarily for operation of various motors and for grinding of fibres. Process heat is used primarily for heating water, other liquids and air, for evaporating water in dry areas of paper machines and for converting steam into electrical energy (with heat/power cogeneration). Large amounts of water are required as process water and for cooling. Various additives are used in paper production, as process aids and to enhance product properties (paper additives).

Most of the waste-gas emissions produced by non-integrated paper mills are produced by steam-production and energy-generation systems. The boilers used in such systems are standard boilers that do not differ from those of other combustion systems. It is assumed that such systems are operated in the same manner as other auxiliary boilers of the same capacity (see below).

Energy-efficient, non-integrated paper mills consume heat and energy on the following scale:

- Non-integrated mills for production of uncoated fine paper consume process heat at a rate of 7 – 7.5 GJ/t and
  energy at a rate of 0.6 – 0.7 MWh/t;
- Non-integrated mills for production of coated fine paper consume process heat at a rate of 7 – 8 GJ/t and
  energy at a rate of 0.7 – 0.9 MWh/t;
- Non-integrated mills for production of tissue from fresh fibre consume process heat at rate of 5.5 – 7.5 GJ/t and
- electrical energy at a rate of 0.6 – 1.1 MWh/t.

Auxiliary boilers

In considering waste-gas emissions from auxiliary boilers, one must take account of the actual energy balance of the pulp or paper mill concerned, the nature of the fuels that are supplied to the facility and any use of biomass fuels such as bark and waste wood. Pulp and paper mills that produce fibre materials from primary fibres normally use bark-fired boilers. Non-integrated paper mills, and mills that process recycled paper, generate waste-gas emissions primarily via their steam-production and/or energy-generation systems. Such systems normally consist of standard boilers that do not differ from those of other combustion systems. It is assumed that such systems are operated in the same manner in which all other systems of the same capacity are operated. The technologies involved include:

- Heat/power cogeneration, where the prevailing heat/power ratio permits;
- Use of renewable fuels, such as wood and any waste wood that is produced, in order to reduce emissions of fossil CO_2;
- Reduction of NO_x emissions from auxiliary boilers, via control of combustion conditions and installation of burners with low NO_x emissions;
- Reduction of SO_2 emissions through use of bark, gas and low-sulphur fuels, and waste-gas scrubbing to remove sulphur compounds;

- Use of effective electrical filters (or tube filters) to separate dust in auxiliary boilers fired with solid fuels.

Overall, most product-specific waste-gas emissions are site-dependent (for example, they depend on the type of fuel used, the size and type of the relevant facility, whether the plant is integrated or non-integrated, whether it generates electricity). The auxiliary boilers used in Germany cover a wide spectrum of different sizes (from 10 to more than 200 MW). With smaller boilers, the only useful approach is to use low-sulphur fuels and the pertinent combustion technologies, while secondary reduction measures can also be effective with larger boilers.

Further information about activity rates is provided in Chapter 12.

14.2.5 Refrigeration and air-conditioning systems (2.F.1)

14.2.5.1 Procedure for calculating emissions from the sub-groups pertaining to "refrigeration and stationary air-conditioning system"

The "household" refrigeration model

1. Determination and aggregation of annual HFC additions since introduction of HFCs (1993)
2. Calculation of annual HFC emissions on the basis of the average size of stocks and of the relevant EF
3. Production and disposal: NO

Refrigeration model for "commercial refrigeration systems"

1. The entire sub-category of commercial refrigeration is divided into numerous system categories. Divisions are based on areas of application (for example, small supermarket) and on system type (for example, central system).
2. For each system category, the number of systems and installed refrigeration output, divided into the categories of low-temperature refrigeration and normal refrigeration, are determined and used as constants. The percentages of systems that are filled with CFCs, HFCs and halogen-free refrigerants are also assumed to be constant. This yields the numbers and installed refrigeration output of all systems that are operated, in the long term, with HFCs (following complete conversion/replacement of old CFC-based systems).
3. For each system category, the relevant refrigerant type, and the refrigerant amount per unit of refrigeration output, are determined.
4. From the data obtained via 1 to 3 above, the end stocks for each refrigerant are determined. Due to the large differences involved, a distinction is made between end stocks for the category "food sales" and "other commercial refrigeration".
5. The end stocks, in connection with the average system service lifetimes (10 years), can then be used to calculate, for both areas, how much refrigerant must be filled annually into new systems (new additions) in order to maintain stocks in the face of removals of old systems (1/10 of stocks). The "average yearly stocks" can also be determined for both areas.
6. Replacement of CFC-based systems is considered separately.
7. Production emissions are calculated by multiplying "new additions" by $EF_{production}$. Production normally takes place at the relevant sites.

8. Emissions from stocks are obtained by multiplying the "average yearly stocks" by the relevant EF_{use}.
9. Disposal emissions occurred for the first time in 2003. $EF_{disposal}$ = 0.3-0.5.

The emission factors on which the emissions data is based are listed in Table 59 wiedergegeben.

Except for $EF_{disposal}$, the emission factors used are the result of surveys of experts and of evaluations of the literature. It should be noted that emission factors have been adapted in line with technical developments for the various reporting years.

"Transport refrigeration / refrigerated vehicles" refrigeration model

1. The entire sub-category of transport refrigerantion / refrigerated vehicles is divided into four size classes of refrigerated vehicles: 2-5t, 5-9t, 9-22t and > 22t GG.
2. Fixed amounts of refrigerants (types), and fixed fill amounts in refrigeration units, are assigned to the various size classes. A fixed share of the market is also assigned to each size class.
3. The number of newly licensed refrigerated vehicles, and the number of refrigerated vehicles filled within the country (broken down by refrigerants), are determined for each year.
4. The annual new additions of refrigerants result from the numbers of newly licensed refrigerated vehicles and the above assumptions.
5. When one knows the existing stocks, one can calculate the average yearly stocks and the year-end stocks.
6. Production emissions are calculated by multiplying the "domestically filled refrigerated vehicles" (for each refrigerant type) by the relevant $EF_{production}$.
7. Emissions from stocks are obtained by multiplying the "average yearly stocks" by the relevant EF_{use}.
8. Disposal emissions occurred for the first time in 2003. $EF_{disposal}$ = 0.3.

The emission factors on which the emissions data is based are listed in Table 59.

Except for $EF_{disposal}$, the emission factors used are the result of surveys of experts. It should be noted that emission factors have been adapted in line with technical developments for the various reporting years.

Refrigeration model for "industrial refrigeration systems"

1. The entire sub-category of industrial refrigeration is divided into numerous system categories. Division is in accordance with industrial sectors and refrigeration levels (normal refrigeration, low-temperature refrigeration and freezing).
2. For each system type, the numbers of systems in service, and the pertinent installed refrigeration output, are assumed to be constant. The percentages of systems that are filled with CFCs, HFCs and halogen-free refrigerants are also assumed to be constant. This yields the numbers and installed refrigeration output of all systems that are operated, in the long term, with HFCs (following complete conversion/replacement of old CFC-based systems).
3. For each system type, the relevant refrigerant type, and the refrigerant amount per unit of refrigeration output, are determined.

4. From the data obtained via 1 to 3 above, the end stocks for each refrigerant are determined.
5. The end stocks, in connection with the average system service lifetimes (10 years), can then be used to calculate how much refrigerant must be filled annually into new systems (new additions) in order to maintain stocks in the face of removals of old systems (1/10 of stocks). The "average yearly stocks" can also be determined.
6. Replacement of CFC-based systems is considered separately.
7. Production emissions are calculated by multiplying "new additions" by $EF_{production}$. Production normally takes place at the relevant sites.
8. Emissions from stocks are obtained by multiplying the "average yearly stocks" by the relevant EF_{use}.
9. Disposal emissions occurred for the first time in 2003. $EF_{disposal}$ = 0.3.

The emission factors on which the emissions data is based are listed in Table 59.

Except for $EF_{disposal}$, the emission factors used are the result of surveys of experts. It should be noted that emission factors have been adapted in line with technical developments for the various reporting years.

Refrigeration model for "stationary air-conditioning systems"

1. Stationary air-conditioning systems are divided into three categories. The number of new systems in each category is determined each year via surveys of experts: Turbo-compressor, screw-compressor, and scroll-compressor and piston-compresor systems. Imports of systems already filled with refrigerant are assumed to be zero.
2. For each category, a certain fill amount and refrigerant composition is assumed.
3. The annual new additions of refrigerant result from the new additions of systems and the above assumptions.
4. When one knows the existing stocks, one can calculate the average yearly stocks and the year-end stocks.
5. Production emissions are calculated by multiplying "number of new systems" by $EF_{production}$.
6. Emissions from stocks are obtained by multiplying the "average yearly stocks" by the relevant EF_{use}.
7. No disposal emissions have occurred to date.

The factors on which the emissions data is based are listed in Table 59.

The emission factors used are the result of surveys of experts. It should be noted that emission factors have been adapted in line with technical developments for the various reporting years.

Refrigeration model for "room air-conditioners"

1. There is no domestic production of room air-conditioners. Room air-conditioners, all of which are imported, are divided into three categories. Annual sales in each category are determined via surveys of sellers: mobile devices, split devices, multi-split devices.
2. For each category, a certain fill amount and refrigerant composition is assumed.
3. The annual new additions of refrigerant result from sales statistics and the above assumptions.

4. When one knows the existing stocks, one can calculate the average yearly stocks and the year-end stocks.
5. There are no production emissions (losses in installation of split and multi-split devices have not been considered in the model to date).
6. Emissions from stocks are obtained by multiplying the "average yearly stocks" by the relevant EF_{use}.
7. No disposal emissions have occurred to date.

The factors on which the emissions data is based are listed in Table 59.

14.2.5.2 Procedure for calculating emissions of "mobile air-conditioning systems"

The following procedure is used to calculate HFC emissions (only HFC-134a) from mobile air-conditioning systems:

1. Determination of annual numbers of newly licensed vehicles, for the classes automobiles, trucks, buses and agricultural machines.
2. Determination of the average rates of installation of air-conditioners in automobiles, trucks buses and agricultural machines. For automobiles, the average rate is based on figures for each vehicle type; these are supplemented as appropriate with figures of industry experts.
3. Determination of the average fill amounts (refrigerant), from figures for each vehicle type (automobiles) and from figures provided by industry experts.
4. Determination of numbers of air-conditioning systems newly installed each year on ships (on the basis of statistics on new ship construction for the German fleet) and in railway vehicles (on the basis of new procurements by German Railways / Deutsche Bahn), and determination of the relevant fill amounts involved.
5. Determination of the annual new additions of 134a, for each pertinent area, from previous figures.
6. Determination of average yearly stocks, and of year-end stocks, for each relevant area, from 5. and the pertinent amounts for the previous year.
7. Emissions from stocks are obtained by multiplying the "average yearly stocks", for each area, by the relevant EF_{use}.
8. Determination of domestic consumption of 134a for production of mobile air-conditioning systems.
9. Production emissions are calculated by multiplying the "domestic consumption" by $EF_{production}$.
10. Disposal emissions occurred for the first time in 2003. $EF_{disposal} = 0.3$.

The factors on which the emissions data is based are listed in Table 59.

The emission factors used were obtained from the literature (e.g. CLODIC & YAHIA, 1997; FISCHER, 1997; ÖKO-RECHERCHE, 2001; ÖKO-RECHERCHE / ECOFYS 2003; PREISEGGER, 1999; SIEGL et al., 2002), measurements (automobiles), evaluations of workshop documentation and comprehensive surveys of experts. In addition to regular emissions during operation, emissions also arise as a result of accidents and other external influences.

14.3 Other detailed methodological descriptions for the source category "solvent and other product use" (3)

14.4 Other detailed methodological descriptions for the source/sink category Agriculture (4)

14.4.1 Agriculture (4) - information on forecasts of agricultural emissions

Germany is unable to calculate projections for agricultural emissions.

14.5 Other detailed methodological descriptions for the source/sink category Land-use change and forestry (5)

14.5.1 Land-use changes and forestry (5.A)

The Greenhouse Gas Inventory 1990-2003 was the first to include C stocks in forest biomass, and their changes, that were derived, on behalf of the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) by the Biometry and Information Science department of Baden-Württemberg's Institute for forestry experimentation and research (Forstliche Versuchs- und Forschungsanstalt (FVA), from Federal Forest Inventory data in keeping with the provisions of the Good Practice Guidance relative to Land-Use, Land-Use Change and Forestry (GPG-LULUCF, IPCC, 2003). These data have been updated for the present inventory by the Institute for Forest Ecology and Forest Assessment of the Federal Research Centre for Forestry and Forest Products.

The C-stock changes in dead wood, debris and forest soils, and the other greenhouse-gas emissions from forests and forest conversion, were not estimated, since complete relevant data and evaluations are not yet available. The provisional assessments made in this regard have been made by the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV).

14.5.1.1 Forest

The basis for reporting consists of the definition of "forest" used by the Federal Forest Inventory (Bundeswaldinventur - BWI)[85].

The BWI's survey instructions differentiate between the following sub-categories of forest:

- Productive forest, wooded ground
- Unproductive forest, wooded ground
- Forest, opening
- Forest, non-wooded ground

[85] Forest within the meaning of the FFI is any area of ground covered by forest vegetation, irrespective of the information in the 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, landings, rides located in the forest, 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. Watercourses up to 5 m wide do not break the continuity of a forest area. The cultivation of Christmas trees and ornamental brushwood in the forest is forest within the meaning of the Federal Forest Inventory (BWI). Areas with forest cover in open pasture land or in built-up areas of under 1000 m², coppices under 10 m wide and the cultivation of Christmas trees and ornamental brushwood as well as parkland attached to country houses are **not forest** within the meaning of the FFI.

In calculations for greenhouse-gas inventories, the categories **unproductive forest** and **openings** were included with forest, while **non-wooded ground**, in keeping with the definition of "forest" used in decision 11/CP.7 of the 7th Conference of the Parties in Marrakesh (UNFCCC, 2002: p. 58) was excluded, as non-forest.

Unproductive forest areas are fields of dwarf pines and green alders, areas of shrubs (but not openings) and other forest areas which are sparsely covered or which have low productivity (≤1 m³ average total growth (dGZ)/hectare).

The **wooded-ground area** is that part of the forest that is covered with trees used in forestry and that is used for wood production.

Non-wooded ground includes forest tracks, rides and firebreaks over 5 m wide, landings, tree nurseries, seed and plant nurseries, wood-pastures and fields for game, the areas of yards and buildings used for forestry purposes, recreational facilities linked to the forest and rocks, boulders, gravel and water located in the forest. In addition, if they are not overgrown, swamps and moors located in the forest come under non-wooded ground.

In the GPG-LULUCF (IPCC, 2003), and in the official reporting tables for the greenhouse-gas inventories sent to the Climate Secretariat (CRF), the category "forest" 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 created, via afforestation or natural succession, on areas previously used for other purposes). Pursuant to IPCC GPG-LULUCF (2003), new forest remains for at least 20 years within this category, after which it is transferred to the "remaining forest land" category.[86]

In Germany, with existing data, new forest additions in the old German Länder can be traced only back to 1987; for the new German Länder, it has been possible only to derive the net new forest since 1993.

14.5.1.1.1 Forest Land remaining Forest Land

14.5.1.1.1.1 Source-category description

14.5.1.1.1.1.1 Changes in biomass

For the old German Länder, data is available from two federal forest inventories (key dates: 1 October 1987 and 1 October 2002). Between the two forest inventories, C stocks in forests of the old German Länder underwent a net increase of 1.52 Mg/ha/a. The increase in stocks is a result of low use, in comparison to growth. For the new German Länder, data from the Federal Forest Inventory II (BWI II) was compared with forest-establishment data, given the lack of an initial inventory comparable to BWI I. The comparison showed a marked net C-stock increase of 3.01 MgC/ha/a.

The forest-establishment data is not completely suited for comparison with the Federal Forest Inventory (BWI). It seems clear that the forest-establishment data underestimates stocks. If the initial value for total stocks is assumed to be 10 % higher (and evenly distributed among all tree species), a marked net C-stock increase of 2.32 MgC/ha/a results.

Overall, the forests of the Federal Republic of Germany are thus a net sink for C.

[86] Countries may choose to remain for longer periods of time in this category, if that seems appropriate to them in light of the time required, under their typical local conditions, for all compartments, including soil, to achieve "typical" forest conditions relative to carbon stocks and its changes.

14.5.1.1.1.1.2 Dead wood, debris and soils

The deadwood stocks of 11.5 m^3/ha found by the BWI II correspond to C stocks of some 2.6 Mg C /ha. Federal Forest Inventory I (BWI I) did not collect data on dead wood, and thus no conclusions can be drawn regarding changes in stocks.

On the whole, more dead wood is now left in forests than was left in the 1950s to 1980s. The reasons for this include changes in demand in the wood market, changes in wood-harvesting methods and an interest in protecting forest biotopes. Storm damage in 1990 and 1999 sharply increased dead wood stocks in some regions. For this reason, it may be assumed that dead wood stocks tended to increase, rather than decrease, between 1990 and 2002.

The inventories did not include a complete survey of debris. Finer debris fractions are part of the humus layer, which was surveyed by the forest-soil-condition survey (BZE).

The BZE estimated the carbon stocks in the humus layer, and in the first 30 cm of mineral soil lying beneath the humus layer, as amounting to about 0.858 Pg C. No conclusions can be drawn regarding changes in stocks, since a subsequent inventory remains to be carried out.

For purposes of greenhouse-gas inventories, therefore, changes in dead wood, debris and soil were neglected, in keeping with the Tier 1 assumption that such stocks do not change in existing forests.

14.5.1.1.1.1.3 Other greenhouse-gas emissions from forests

Figures for CO_2 emissions from liming of forest floors are provided in category 5.G (Other). They range between 130 and 210 Gg CO_2 per year, and are tending to decrease.

BUTTERBACH-BAHL (2003), using the PnET-N-DNDC model, estimated total nitrous oxide (N_2O) emissions from forest soils for the years 1990-1999 as amounting to about 14 Gg per year. This includes the effects of considerable nitrogen discharges from deposition of nitrogen compounds, from emissions of industry, and from the energy, residential, transport and agriculture sectors.

These "indirect" N_2O emissions, which must be assigned to sources outside of the forestry sector, are outside the scope of greenhouse-gas inventories in the area of land-use changes and forestry, however. Reporting in this area includes only N_2O emissions from nitrogen fertilisation of forest soils and from drainage of forest soils.

Forests in Germany are not normally given nitrogen fertilisers. In CRF Table 5(I), therefore, this activity has been marked "NO".

In the 19th and early 20th centuries, many wet locations were drained and afforested, and forested wet locations were "ameliorated", via drainage, in order to increase yields. Some of the drainage ditches from that era are still present in today's forests. In addition, in the second half of the 20th century, areas were afforested that had previously been drained as a means of obtaining or enhancing agricultural land. There is a lack of reliable data for reporting on this category, however (CRF 5(II)).

N_2O, CH_4, NO_x, CO and other gases are released in forest fires and in controlled burning of biomass (for example, in burning-off of logged areas following wood harvesting).

The areas in which forest fires occur in Germany are small and, since surveys commenced, have decreased markedly as a result of improved forest-fire prevention and response. Only in 2003, a year with months of continuing dryness and extreme heat, did they increase again.

Table 145: Areas affected by forest fires [ha]

1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
3.267	1.493	1.114	592	1.381	599	397	415	581	122	122	1.315	274

Forest-fire statistics (BML 1992 ff., Part G., Table „Waldbrände und ihre Ursachen“ ("Forest fires and their causes")) unfortunately include no data on the amounts of biomass effectively burned; such data would at least support rought estimates, in keeping with "Tier 1", of the relevant amounts of gases released. In light of the small size of the areas in question, this source is considered negligible, and "NO" has been entered in Table 5 (V) "Biomass burning" next to N_2O and CH_4.

This also applies to controlled burning of biomass. Burning-off of vegetated areas is prohibited in Germany. Burning of unusable crown parts and branches is carried out in exceptional cases, in combatting of bark beetles. Increasingly, other methods (chopping, crushing) are also being used for this purpose.

As a result of use of the "stock-change method" (cf. Chapter 7.1.1.2.3), CO_2 from biomass combustion has already been taken into account in changes of biomass stocks; the entry for this category is thus "IE".

14.5.1.1.1.2 Methodological issues

14.5.1.1.1.2.1 Data sources

The basis for the biomass and area calculations consists of the data from the two Federal Forest Inventories. Pursuant to provisions of the IPCC GPG-LULUCF (2003), this data is processed in keeping with requirements pertaining to international reporting obligations.

The Federal Forest Inventory is a terrestrial random-sampling inventory with permanently marked sampling points. Data collection is carried out at the corners of about 44,000 quadratic plots, with side lengths of 150 m, that are distributed systematically throughout the entire country. As in the first Federal Forest Inventory, random sampling is distributed throughout a 4 x 4 km basic grid whose resolution may be increased, at Länder request, on a regional basis. A double random-sampling density is used in parts of Bavaria, Lower Saxony and Thuringia, and a quadruple sampling density is used in the Länder Baden-Württemberg, Mecklenburg-West Pomerania, Schleswig-Holstein and Rhineland-Palatinate[87].

The first Federal Forest Inventory, BWI I, covered only the territory of the Federal Republic of Germany in its pre-1990 boundaries and West berlin. For the new German Länder, therefore, forest-establishment data has to be taken from another source – the publication "The Forest in the New German Länder" ("Der Wald in den neuen Bundesländern" (BML, 1994)).

Due to the differences in the data situations for the two areas, and to the resulting need to use different calculation methods, reporting in the CRF tables is broken down by old and new German Länder.

The Federal Forest Inventory II (BWI II) took a first accounting of dead wood, and thus no information can yet be provided regarding changes in dead-wood stocks. The dead-wood stocks of 11.5 m^3/ha found by the BWI II correspond to C stocks of some 2.6 Mg C /ha.

The first soil condition survey, which was carried out from 1987 to 1993 (BMELF, 1997), supports estimates of carbon stocks in humus layers and mineral soils; it does not support

[87] Further information: http://www.bundeswaldinventur.de

estimates regarding changes in such stocks, however. These carbon stocks (humus layer and the first 30 cm of mineral soil) were estimated at about 0.858 Pg C (BMELF, 1997).

Data on liming of forest soils was derived from fertiliser statistics (Düngemittelstatistik) (DESTATIS, Fachserie (technical series) 4, Reihe 8.2). Until 1992/93, the results published by the Federal Statistical Office referred to the territorial status of the former Federal Republic of Germany. For the territory of the former GDR, the Federal Ministry of Consumer Protection, Food and Agriculture (BMELV) adapted data for the years 1950 to 1989, based on GDR statistics, to the fertiliser-statistics categories of the Federal Republic of Germany, to facilitate comparison. Due to a lack of relevant surveys, data on fertiliser consumption in the former GDR during the years 1990-1992 was extrapolated linearly. From 1993/94 onwards, the results have been collected and published for unified Germany.

Since 1992, data on areas on which forest fires have occurred is available in official forest-fire statistics pursuant to Council Regulation (EEC) No. 2158/92 of 23 July 1992 on protection of the Community's forests against fire.

14.5.1.1.1.2.2 Forest land remaining as forest land

Forest-area data is not required for calculation of biomass stocks pursuant to the "stock-change method", but it must be reported in the CRF. The area data for individual years is based on linear interpolation.

For the old German Länder, such data can be derived from the results of the two Federal Forest Inventories. In that region, the total forest area (not including non-wooded ground) increased by 54.12 kha, to 7,693.72 kha. Pursuant to IPCC GPG-LULUCF (2003), new forest must be classified as "new forest" for a period of 20 years, and thus each year the category "forest land remaining forest land" is reduced by that forest area converted to other land uses. As a result, the category "forest land remaining forest land" decreased from 7,626.14 kha (1990) to 7,572.27 kha (2002).

The only recourse for the new German Länder, therefore, is to compare BWI II data and forest-establishment data from the publication "The Forest in the New German Länder" ("Der Wald in den neuen Bundesländern" (BML, 1994)).

According to forest-establishment data, in the new German Länder, the forest area (not including non-wooded ground) in 1993 amounted to 2,852.5 kha; by BWI II it had increased to 3,027 kha. As a result, the first of these values can assigned to the category "forest land remaining forest land".

14.5.1.1.1.2.3 Derivation of stock changes pursuant to the "stock-change method" (difference method)

The Federal Forest Inventories provide an outstanding database for calculating C stocks and their changes. They provide such good data for calculation – measuring about 230,000 trees in key year 1987 (BWI I) and some 377,000 trees in key year 2002 (BWI II) – that it was possible to use the "stock-change method" instead of the "default method" (incremental extrapolation, as carried out for previous inventories) (IPCC, 2003: p. 3.24). For use of the "stock-change method", the categories: standing-timber volume, branch wood volume and root mass were separated. Above-ground volumes were converted into masses using specific basic densities for the various tree species in question. The basic equation (Equation 23 and Equation 24) for C-stock determination via the stock-change method was thus converted into a form pursuant to Equation 25. The first part of Equation 25 (standing timber, branch wood) was applied to each tree, while the second part was applied to stands. The total value was then extrapolated from the stand values.

Equation 23

$$\Delta C = \left(C_{t_2} - C_{t_1}\right) / \left(t_2 - t_1\right)$$

Equation 24

$$C = \left[V \bullet D \bullet BEF\right] \bullet \left(1 + R\right) \bullet CF$$

Equation 25

$$C = [\underbrace{V \bullet D_D}_{\text{Standing timber}} + \underbrace{V \bullet D_A \bullet (VEF - 1)}_{\text{Branch wood}}] \bullet \underbrace{(1 + R)}_{\text{Root wood}} \bullet CF$$

where:
C = carbon stocks
V = volume of standing timber
D_D = basic density of standing timber
D_A = basic density of branches
BEF = biomass-expansion factor
VEF = volume-expansion factor[88]
R = root / sprout relationship
CF = carbon fraction

14.5.1.1.1.2.4 Procedure

For central European conditions, there are no generally valid biomass functions that could have been applied to the inventory's measured data (a function for spruce is one exception). These functions directly yield tree dry masses, usually with the input quantities breast-height diameter (BHD) and height (H). Unfortunately, existing biomass studies comprise only small numbers of random samples, and they represent only local growth and site conditions, along with relevant variations in management. Use of such data would distort extrapolations.

For this reason, a procedure was applied whereby the standing-timber volume, as determined in the inventory, is converted into the above-ground tree volume. The above-ground tree volume includes branches and, for evergreen trees, the leaf organs. To estimate tree wood volumes from standing timber volumes, linear regression equations are used that describe the relationship between above-ground standing-timber volume and the above-ground tree wood volume. These equations (volume-expansion functions) were derived from the tables of GRUNDNER & SCHWAPPACH (1952), which are based on an extensive database comprising 71,051 trees.[89]

In a next step, the trees' above-ground mass was calculated from tree wood volume, via basic density data. A range of different basic density figures were used. Among these are the

[88] The biomass-expansion factor (BEF) is used here in keeping with IPCC. In the literature, the term "BEF" is used in a variety of very different ways. For this reason, in the following, the term "volume-expansion factors" (VEF) is used, which describes the relationship above-ground volume / standing-timber volume.
[89] Since the regressions describe the relationship between rounded table values, the actual variation is not taken account of, and no true prediction error can be given. Such an error could be given if the original data were available as a base for calculating new tree wood-volume functions.

basic densities of KNIGGE & SCHULZ (1966), as they are used, for example, by BURSCHEL et al. (1993). Other wood-science handbooks, such as BOSSHARD (1984), use density figures of KOLLMANN (1982). The default values pursuant to IPCC (2003) also provide basic densities for many native tree species. Since densities have a direct influence on total carbon stocks, 3 different density extrapolations were used for the individual-tree calculations.

Since above-ground expansion of standing-timber volume into tree wood volume was carried out, the various wood categories can be separated in order to take the higher basic densities of branches (HAKKILa, 1972) into account. Such separation was carried out for densities pursuant to KOLLMANN (1982) and IPCC GPG-LULUCF (2003). In the third extrapolation, the procedure pursuant to BURSCHEL et al. (1993) was methodically applied, with constant basic densities, to above-ground volumes, in order to permit comparison with other scenarios.

The underground living biomass was taken into account via stock-mass relationships. To this end, the above-ground biomass, broken down by tree species, was extrapolated to hectare values for each random-sample point. This value was then used to derive root biomass. Root masses were calculated with the help of two sources (DIETER & ELSASSER, 2002; IPCC, 2003). Overall, three extrapolations for above-ground C stocks, and 6 calculations of underground C stocks, are thus available. In addition, results for spruce can be compared with the general biomass function of WIRTH et al. 2004b. The various calculations may be seen as scenarios that approximate the actual circumstances and that can reveal the range of deviations and their sensitivity.

For the new German Länder, forest-establishment data is available in aggregated form. For this reason, the C-balancing method pursuant to BURSCHEL et al. (1993), in conjunction with basic densities pursuant to KOLLMANN (1982), was used for C-stock determination.

14.5.1.1.1.2.5 Total stocks of remaining forest land

The results described here refer, in connection with individual-tree calculations for BWI I and BWI II, to basic densities pursuant to KOLLMANN (1982), whereas branch volumes, with their greater densities, were extrapolated pursuant to HAKKILA (1972). Above-ground tree volume was estimated with the function coefficients from Table149. Root biomass was calculated using default values from IPCC GPG-LULUCF (2003). In the extrapolation for the new German Länder for 1993, the biomass-expansion factors (BEF) of BURSCHEL et al. (1993) were separated into above-ground and below-ground components, and the upper branch volume was estimated from the difference between above-ground volume and standing-timber volume. In the interest of comparability between the extrapolation of forest-establishment data and individual-tree calculation pursuant to BWI, the same basic densities were used throughout this process.

Table146: Total C stocks, remaining forest

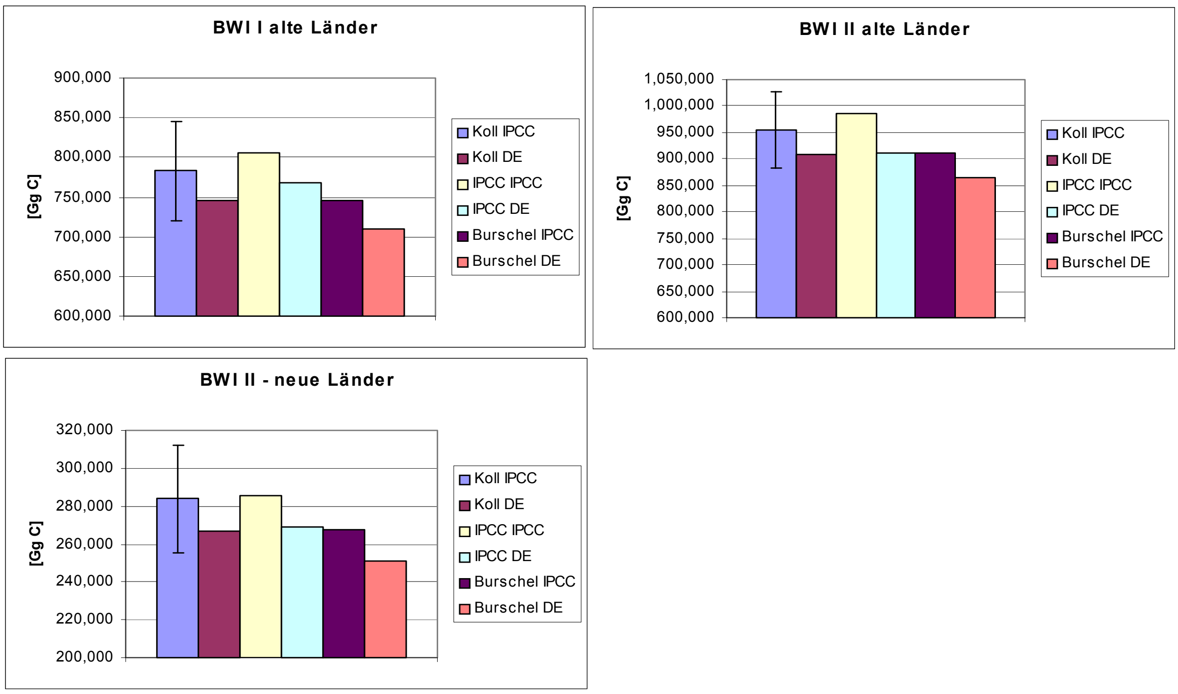
Gg C		1987 (BWI I)	1993 (BML)	2002 (BWI II)
Old German Länder	below ground	174,670	-	212,849
	above ground	604,474	-	740,481
	Total	**779,144 (± 8%)**	**-**	**953,330 (± 7.55%)**
New German Länder	below ground	-	34,723	63,690
	above ground	-	161,766	218,667
	Total	**-**	**196,489 (±12.71 %)**	**282,357 (± 10.02 %)**

14.5.1.1.1.2.6 Total stocks in various scenarios

The scenario calculations were carried out only for the individual-tree calculations. The error bar shows the simple standard error. For determination of the 95% confidence interval, this range must be doubled. The bars on the left in each approximately correspond to the values in Table146, since in these cases the entire forest area (not including non-wooded ground) was considered. The abbreviations are to be understood as follows: the first refers to the above-ground basic density assumptions (Table147), while the second refers to the underground density assumptions (Table150, Table151).

The last scenario in each case is also considerably below the other extrapolations. This is due to an underestimation of basic densities, since, pursuant to Burschel et al. (1993), no separation was made between branch volume and standing-timber volume; such separation would lead to correspondingly higher basic densities for branches.

Figure 72: Total stocks in various scenarios[90]



[90] top: old German Länder, bottom: new German Länder

14.5.1.1.1.2.7 Basic density of stem (trunk) wood

In light of basic densities' strong influence on carbon balance, various basic densities (i.e. the relationship between dry weight and fresh-wood volume) were used. In two scenarios, the basic densities from KOLLMANN (1982) and IPCC GPG-LULUCF (2003) were used and linked with higher branch densities (see above).

The raw densities pursuant to KOLLMANN (1982: Annex, tables V) give the raw-density ranges and their average values for the most important tree species. These ranges were also used as a basis for error calculation. The basic densities were calculated from the raw densities, via relevant volume-loss measures.

Equation 20

$$R = r_0 * \left(1 - \frac{\beta_V}{100} \right)$$

R= basic density (g/cm^3)
r_0= raw density (g/cm^3)
$ß_V$= volume-loss measure

For comparison, an extrapolation without this branch-wood correction, and with the basic densities used by Burschel et al. (1993) from Knigge & Schulz (1966), was carried out. The resulting basic densities differ only between tree-species groups.

Table 147: Basic densities

		Basic density (R) [g/cm³]					
Genus	**Species**	**Stem (IPCC)**	**Branch (IPCC)**	**Stem (Kollmann)**	**Branch (Kollmann)**	**Knigge Schulz (Branch and stem)**	**βV (%) (Kollmann)**
Picea	**abies**	0,40	0,54	0,3788	0,5093	0,3771	11,9
Picea	**(other)**	0,40	0,54	0,3788	0,5093	0,3771	11,9
Pinus	**sylvestris**	0,42	0,56	0,4307	0,5790	0,4307	12,1
Pinus	**strobus**	0,32	0,43	0,4307	0,5790	0,4307	12,1
Pinus	**(other)**	0,42	0,56	0,4307	0,5790	0,4307	12,1
Abies	**alba**	0,40	0,54	0,3629	0,4878	0,3700	11,5
Abies	**(other)**	0,40	0,54	0,3629	0,4878	0,3700	11,5
Pseudotsuga	**menziesii**	0,45	0,60	0,4141	0,5567	0,4124	11,9
Larix	**decidua**	0,46	0,62	0,4873	0,6551	0,4873	11,4
Larix	**kaempferi**	0,49	0,66	0,4873	0,6551	0,4873	11,4
Thuja	**spec.**	0,31	0,42	0,3788	0,5093	0,3771	11,9
Tsuga	**spec.**	0,42	0,56	0,3788	0,5093	0,3771	11,9
Nadelbäume	**(other)**	0,40	0,54	0,3788	0,5093	0,3771	11,9
Fagus	**sylvatica**	0,58	0,64	0,5583	0,6119	0,5543	17,9
Quercus	**robur**	0,58	0,62	0,5707	0,6056	0,5611	12,2
Quercus	**petraea**	0,58	0,62	0,5707	0,6056	0,5611	12,2
Fraxinus	**exelsior**	0,57	0,60	0,5642	0,5987	0,5642	13,2
Carpinus	**betulus**	0,63	0,69	0,6415	0,7031	0,5642	18,8
Acer	**spec.**	0,52	0,57	0,5222	0,5723	0,5642	11,5
Tilia	**spec.**	0,43	0,47	0,4170	0,4571	0,5642	12,1
Robinia	**pseudoacacia**	0,58	0,64	0,6468	0,7089	0,5642	11,5
Ulmus	**spec.**	0,51	0,54	0,5555	0,5895	0,5642	14,9
Castanea	**sativa**	0,48	0,51	0,5583	0,5924	0,5642	11,4
Betula	**spec.**	0,51	0,56	0,5264	0,5770	0,3768	13,2
Alnus	**spec.**	0,45	0,49	0,4283	0,4694	0,3768	17,9
Populus	**spec.**	0,35	0,38	0,3538	0,3878	0,3768	13,7
Salix	**spec.**	0,45	0,49	0,4618	0,5061	0,3768	13,7
Prunus	**spec.**	0,49	0,54	0,5583	0,6119	0,3768	12,6
Deciduous	**(other)**	0,58	0,64	0,5583	0,6119	0,3768	13,7

14.5.1.1.1.2.8 Basic densities of branches

Pursuant to Equation 25, other basic densities are assumed for branches. Due to the stresses it is subject to, branch wood is denser than trunk/stem wood. Separation into various categories makes it possible to use different densities. The necessary data was derived by analogy to HAKKILA (1972), who divides trees by physiological groups, into conifers, ring-porous broadleaves and diffuse-porous broadleaves.

Table148 shows average values for 8 conifers, 8 ring-porous broadleaves, 4 diffuse-porous broadleaves. A relationship for these physiological tree-species groups was derived, and the basic densities were correspondingly increased.

Table148: Basic densities, branches

	Stem wood [g/cm³]	Branch wood [g/cm³]	Ratio Brandh/stem density
Conifers	0,363	0,488	1,3444
Diffuse-porous broadleaves	0,489	0,536	1,0961
Ring-porous broadleaves	0,54	0,573	1,0611

14.5.1.1.1.2.9 Volume-expansion factors

For above-ground expansion, BURSCHEL et al. (1993) used the brushwood percentages of GRUNDNER & SCHWAPPACH (1952). They have the advantage of being generally valid for central European conditions and of representing a large number of sample trees. This extrapolation has often been criticised for being too coarse, since the brushwood percentages are shown in the tables only as aggregated values. What is more, WIRTH et al. (2004a) note that use of BEF (remark: this refers to volume-expansion factors, i.e. the relationship between standing-timber volume and total tree volume) pursuant to BURSCHEL et al. (1993) probably results in underestimation of biomass stocks, since the various categories (compartments) were not separated, to permit use of different basic densities.

For this reason, a different approach was selected for these calculations. First, a compartment-oriented calculation was carried out, divided into three tree-part categories (standing timber, tree wood, root wood). In addition, in preparation of generally valid volume-expansion factors (VEF) for above-ground expansion, brushwood tables were not used; instead, data from the tables of GRUNDNER & SCHWAPPACH (1952), for standing timber and tree wood, was placed into a linear regression. These factors provide a functional relationship between standing timber and tree wood; this relationship is shown in the tables. This relationship makes it possible to estimate tree wood from the size of standing timber, which itself depends on the measured values BHD, height and D7. In addition, the tables call for separation, by age classes, for the tree species spruce, fir, beech and pine, since for these trees it was found that, for trunks with the same dimensions, older trunks have a greater volume than younger trunks; the older trunks have a greater wood fraction. This separation was retained, since the tables on based on separate basic totalities.

First of all, various models were tested for predicting tree-wood volume from standing timber, models with varying terms for diameter and height. It emerged that the models could be improved somewhat via inclusion of diameter and height (as BHD^{2}*height) as predictors. Unfortunately, use of these models has shown that the Federal Forest Inventory (BWI) database includes trees that depart sharply from the normal allometry. This produced tree-wood volumes that were smaller than the corresponding standing-timber volumes. As a result of this implausibility, these models were not used; instead, models with simple linear regression were used. The relevant relationships are shown in the following Table149:

Table149: Above-ground expansion functions

Model	a	b
Birch	0,017493	1,121933
Beech, age 61 to 100	0,008184	1,196184
Beech, age at least 101	0,030255	1,128104
Beech, age to 60	0,011942	1,207371
Oak	0,101879	1,051529
Alder	0,004825	1,068903
Spruce, age at least 61[1]	0	1,177947
Spruce, age to 60	0,036697	1,148143
Pine, age at least 81	0,036883	1,076103
Pine, age to 80	0,009946	1,156659
Fir, age to 80	0,019457	1,168262
Fir, age 81 to 120[269]	0	1,228069
Fir, age at least 121[269]	0	1,219492
Larch	0,063265	1,057712

Tree-wood volume = a + b * standing-timber volume

This leads to the following relationship for volume-expansion factors:

Equation 27:

$$VEF = \frac{B}{D} = \frac{a + bD}{D}$$

B=Tree-wood volume
D=Standing-timber volume
VEF=Volume-expansion factor

14.5.1.1.1.2.10 Root biomass

In contrast to derivation of above-ground biomass, the root dry substance was not calculated via a volume and the basic density; instead, it was established directly from the above-ground mass. Dry-root substance was estimated using the root/shoot ratio, with values pursuant to IPCC GPG-LULUCF (2003). To obtain stand values, the above-ground biomass, differentiated by tree-species groups, was extrapolated to the hectare level for each sampling point, and then the underground biomass was derived.

Because root studies are so difficult to carry out, few root-biomass functions are available. For this reason, the relationships derived in so-called "meta-analyses" were used. For example, DIETER & ELSASSER 2002 published a function for estimating root biomass. In the main, this function is based on data, for temperate forests, of CAIRNS et al. (1997), KURZ et al. (1996) and VOGT et al. (1996). They achieved a random-sampling set of 272 root studies.

Equation 28

$$\sqrt{rb} = \beta * \sqrt{ab} + \delta_{treespecies} + \varepsilon$$

where:
ab = Above-ground biomass
rb = Root biomass

It must be remembered that this derived function is oriented to stand values that always refer to one hectare.

Table150: Root biomass

Tree Species	β	δ	Degrees of freedom	Sig.-level	r^2
Abies	0,4259	1,8114	266	**	0,8
Picea		1,169		**	
srb		0,691		**	
Pseudotsuga		0,4738		*	
Pinus		0,2864		*	
Fagus and Quercus		0			

For below-canopy and "selection forest" (Plenterwald), the authors assumed an average R/S (biomass) value of 0.18.
srb = short rotation broadleaves (in BWI= ALN)
* Significant α< 5%, ** Significant α<1%.
Source: Dieter & Elsasser 2002

Since these calculations are subject to a great deal of uncertainty, a scenario with the values pursuant to IPCC (2003) was also calculated. The advantage of the IPCC table is that it includes the standard error in the estimates; this is not included in the study of DIETER & ELSASSER 2002. The values entered into the CRF tables were derived pursuant to IPCC (2003.

Table 151: Root mass

Vegetation type	Above-ground biomass [t/ha]	Mean	SD	lower range	upper range
Conifer plantation	<50	0,46	0,21	0,21	1,06
Conifer plantation	50-150	0,32	0,08	0,24	0,5
Conifer plantation	>150	0,23	0,09	0,12	0,49
Oak forest	>70	0,35	0,25	0,2	1,16
Other broadleaf	<75	0,43	0,24	0,12	0,93
Other broadleaf	75-150	0,26	0,1	0,13	0,52
Other broadleaf	>150	0,24	0,05	0,17	0,3

Source: IPCC 2003

The following Figure73 shows the R/S values for fir and spruce, along with the average R/S relationship pursuant to DIETER & ELSASSER 2002. In addition, the relevant values pursuant to IPCC GPG-LULUCF (2003: "Conifer Plantation") are included for comparison.

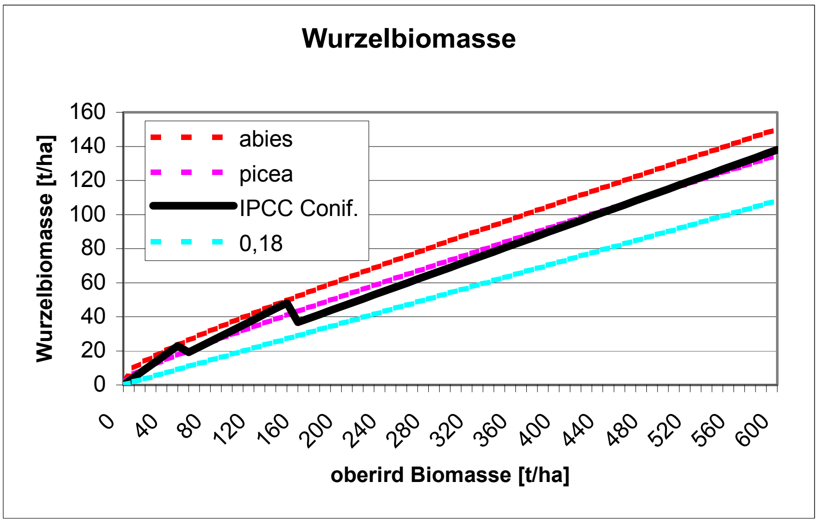


Figure73: Root biomass [root biomass; above-ground biomass]

14.5.1.1.2 Derivation of CO_2 emissions from liming of forest soils

The data for liming was derived from the overall calculation for fertilisers. For this reason, sampling errors cannot be specified. Because companies have a statutory duty to supply information, the data collection is complete.

The data describes deliveries, by producers and importers, to wholesalers and end users. It does not provide direct information on the annual use of fertilizers in agriculture and forestry. Deviations from actual fertiliser use are possible

- due to changes in commercial stocks
- due to use of fertiliser outside of agriculture and forestry, e.g. on private land, gardens, sports facilities

The relevant emissions were derived using equation 3.3.6 from IPCC GPG-LULUCF (2003: p. 3.80).

14.5.1.1.2.1 Uncertainties

For the old German Länder, stratification was carried out in accordance with tree-species groups pursuant to BWI (ALH[91], ALN[92], beech, douglas fir, oak, spruce, pine, larch, fir). To this end, the relative standard error is estimated or calculated for each input item (standing-timber volume, basic density, above-ground biomass expansion, root biomass and carbon fraction). This relative standard error is then extrapolated using the extrapolation procedure in question – additive error propagation or multiplicative error propagation. The calculation does not take account of every possible error source (divergence of allometry, model errors in standing-timber calculation). For this reason, the following assumptions must always be seen as a way of approximating the actual error values. Where assumptions had to be made, they tended to be made carefully (with higher error).

As a result, the relative standard error for the total stocks was obtained. The 95% confidence interval for this estimate corresponds to double the relative standard error.

[91] ALH = all other deciduous trees with high life expectancies
[92] ALN = all other deciduous trees with low life expectancies

Equation 29

$$U_{tot} = \frac{\sqrt{\sum_i (U_i \bullet x_i)^2}}{\sum_i x_i}$$

where
Ui Uncertainty in quantity i
xi Quantity

For the new German Länder, C stocks can be calculated only as estimates, based on aggregated values; this is accomplished pursuant to the publication "The forest in the new German Länder" ("Der Wald in den neuen Bundesländern" (BML 1994)). The calculations continue to be carried out separately with respect to Federal Forest Inventory I (BWI I), BWI II new German Länder and BWI II old German Länder.

14.5.1.1.2.1.1 Uncertainties, standing-timber stocks

For BWI I, random-sampling errors can be taken from the publication "Bundeswaldinventur" ("Federal Forest Inventory", BMELF 1990). The random-sampling errors for BWI II were taken (separated by tree-species group and German Länder) from the Internet[93]. For error extrapolation from the Länder level to the level new/old German Länder, error propagation by sums was used (Equation 29). The model errors cannot be calculated via estimation of standing timber, since relevant studies for this are lacking.

Table 152: Relative standard error, standing-timber stocks

Tree-species group	BWI II New German Länder rel. s (stocks)	BWI II Old German Länder rel. s (stocks)	BWI II total rel. s (stocks)	BWI I Old German Länder rel. s (stocks)
EI[94]	4,31%	2,24%	2,1%	2,5%
BU	4,23%	1,96%	1,8%	2,0%
ALH	4,85%	2,61%	2,4%	3,1%
ALN	3,84%	2,94%	2,4%	3,3%
FI	3,48%	1,59%	1,5%	1,4%
TA	40,40%	3,76%	3,8%	3,3%
DGL	13,94%	4,14%	4,0%	6,0%
KI	2,46%	2,28%	1,7%	2,0%
LÄ	5,87%	3,65%	3,2%	3,7%

14.5.1.1.2.1.2 Uncertainties, basic density

Wood basic densities differ from species to species and can fluctuate within one and the same tree. KOLLMANN (1982) gives variation ranges for raw densities. With the held of these variation ranges, the standard error can be estimated pursuant to SACHS (1984). For left-leaning and right-leaning distributions (approximations of triangular distributions) of basic densities, distributions that are actually seen in trees (BOSSHARD 1984; KOLLMANN 1982), the range is divided by 4.2. It was not possible to take account of the error arising in conversion of raw density into basic density, since no relevant data is available. In this case, it was assumed that this error would not affect the basic-density range.

[93] http://www.bundeswaldinventur.de/testergebnisse/
[94] EI oak, BU beech, FI spruce, TA fir, DGL Douglas fir, KI pine, LÄ larch

Table 153: Relative standard error, basic density

Tree species	Average raw density	min. raw density	max. raw density	Standard error, estimated	Rel. standard error
BU[95]	0,68	0,49	0,88	0,0929	13,66%
DGL	0,47	0,32	0,73	0,0976	20,77%
EI	0,65	0,39	0,93	0,1286	19,78%
LÄ	0,55	0,4	0,82	0,1000	18,18%
ES (ALH)	0,65	0,41	0,82	0,0976	15,02%
FI	0,43	0,3	0,64	0,0810	18,83%
KI	0,49	0,3	0,86	0,1333	27,21%
PA (ALN)	0,41	0,37	0,52	0,0357	8,71%
TA	0,41	0,32	0,71	0,0929	22,65%

For secondary tree-species groups that are relatively unimportant in terms of numbers, including broadleaves with high life expectancies (4.4 % of total standing-timber volume) and broadleaves with low life expectancies (5.2 %), the values for ash and poplar were used.

14.5.1.1.2.1.3 Uncertainties for volume expansion

The natural variability of above-ground allometry is not included here. This error cannot be calculated, since the original figures of GRUNDNER & SCHWAPPACH (1952) are not available. The tables contain only averaged values. These smoothed values systematically underestimate the actual variance.

This error consideration thus calculates only the error for conversion of standing-timber volume into tree-wood volume. The standard error of residues of the models is shown in the following Table154:

Table 154: Relative standard error, VEF model

Model		Average (calculated tree wood)	s(residues)	Rel. standard error
Oak		4,688483	0,1921357	4,10%
Birch		0,6871404	0,007478048	1,09%
Alder		0,6902273	0,006260212	0,91%
Beech	**Age to 60**	0,3631021	0,01984793	5,47%
Beech	**Age 61 to 100**	1,253777	0,05095927	4,06%
Beech	**Age at least 101**	2,665235	0,06851797	2,57%
Spruce	**Age to 60**	0,4466276	0,05036626	11,28%
Spruce	**Age at least 61**	3,595929	0,1637905	4,55%
Pine	**Age to 80**	0,6035531	0,01861142	3,08%
Pine	**Age at least 81**	2,112509	0,06913789	3,27%
Fir	**Age to 80**	0,8898365	0,05534219	6,22%
Fir	**Age 81 to 121**	3,526363	0,2644826	7,50%
Fir	**Age at least 121**	6,980293	0,6241895	8,94%
Larch		3,209294	0,07115059	2,22%

Since the errors for a given tree species, with respect to age classes, can vary considerably, the errors from the extrapolation are amount-weighted with the stocks from BWI I and BWI II. The following values were thus determined:

[95] ES ash, PA poplar

Table 155: Errors VEF model, tree-species groups

	BWI IRSE	BWI II, a.Bl. RSE	DS Waldfonds RSE	BWI II, n.Bl. RSE
BU	3,55%	3,47%	3,40%	3,41%
ALH	4,22%	4,37%	4,55%	4,37%
ALN	5,01%	5,10%	5,01%	4,94%
FI	7,08%	7,16%	6,89%	7,06%
TA	7,32%	7,70%	6,91%	7,49%
DGL	9,63%	9,89%	10,01%	9,94%
KI	3,16%	3,18%	3,14%	3,14%

RSE = relative standard error

14.5.1.1.2.1.4 Uncertainties, root biomass and carbon content

The standard errors in root-biomass calculation can only be obtained from the tables pursuant to IPCC GPG-LULUCF (2003). Here as well, amount-weighted error extrapolation was carried out. To carry out error propagation by sums (IPCC, 2000: Equation 6.3), the sums of above-ground mass calculations were calculated for each stratification of the table; it was then possible to derive the total errors for conifers, oak, and other broadleaves.

The following values then resulted:

Table 136: Relative standard error, root

	BWI I	BWI II
Conifers	25,34%	25,45%
Oaks	58,11%	59,17%
Broadleaves	19,34%	19,07%

The relative standard error for carbon content in wood is given by BURSCHEL et al. (1993) as 1-2%; WEISS et al. (2000) use 2 %. WIRTH et al. (2004a) 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 0.5-0.56 gC/g in conifers. Overall, therefore, a mean C content of 0.5 gC/g, as a good assumption for average content, and with a relative standard error of ±2 %, seems appropriate.

14.5.1.1.2.1.5 Error estimation for the new German Länder, 1993

Since C-stock calculation for the new German Länder was possible only with the method pursuant to Burschel et al. 1993, taking account of data in the publication: "Der Wald in den neuen Bundesländern" ("The Forest in the New German Länder", BML, 1994), the procedure for the old German Länder can be adopted here only partially.

On p. 9 of this publication, the following statement about errors relative to stocks is made: "The stocks on the sub-area were determined, in the framework of the forest-establishment procedure, with a mean standard error of ±12.5 %." Assuming that this error has had a systematic impact on extrapolation, a value of ±12.5 % may be assumed for tree-species groups.

The basic densities pursuant to BURSCHEL et al. (1993) exhibit no range; for this reason, the basic-density variations pursuant to Table147 are used.

The biomass-expansion factors of Burschel et al. (1993) were divided into above-ground and below-ground components. As an approximation for above-ground expansion, therefore, the values from Table155 can be accepted, with a small addition for aggregation in the brushwood-percentage class averages. Since the data situation for underground root percentages is unclear, as an approximation the standard errors of IPCC GPG-LULUCF (2003), as derived in 4.4, are used.

Following multiplicative error propagation

Equation 30

$$U_{tot} = \sqrt{\sum_i U_i^2}$$

for above-ground parts, and summing (Equation 29) of tree-species groups, the following overall value was derived:

Table157: Error estimation, new German Länder, 1993

	RSE standing timber	RSE density	RSE VEF above-ground	RSE VEF aggr. (+ 1%)	above ground total RSE	below-ground total RSE	RSE above-ground + below-ground	RSE C content	RSE C calculation	RSE dead wood
Ei	12,50%	19,78%	4,10%	5,10%	23,95%	59,17%	22,35%	2,00%	22,44%	12,78%
Bu	12,50%	13,66%	3,40%	4,40%	18,76%	19,07%	15,79%	2,00%	15,92%	
Alh	12,50%	15,02%	4,55%	5,55%	19,91%	19,07%	16,80%	2,00%	16,92%	
Aln	12,50%	8,71%	5,01%	6,01%	15,97%	19,07%	13,65%	2,00%	13,80%	
Fl	12,50%	18,83%	6,89%	7,89%	23,40%	25,45%	19,38%	2,00%	19,48%	
Ta	12,50%	22,65%	6,91%	7,91%	26,45%	25,45%	22,28%	2,00%	22,37%	
Dgl	12,50%	20,77%	10,01%	11,01%	26,26%	25,45%	21,73%	2,00%	21,82%	
Ki	12,50%	27,21%	3,14%	4,14%	30,13%	25,45%	25,17%	2,00%	25,25%	
Lä	12,50%	18,18%	2,22%	3,22%	22,30%	25,45%	18,85%	2,00%	18,96%	

RSE = relative standard error

Many of these values are estimates and thus cannot be considered true errors.

14.5.1.1.2.1.6 Total error

For estimation of the total errors for BWI I, old German Länder, and BWI II, new and old German Länder, the values for the tree-species groups can be combined, for each individual calculation factor. For the above-ground error propagation (standing-timber volume, biomass expansion, density), the multiplicative error propagation can be (Equation 30). Since calculated underground C stocks are added to the above-ground stocks, error propagation by sums must again be assumed (Equation 29). The same applies for the summation over all tree-species groups. The following Table158 summarises the various individual rel. standard errors:

Table 158: Error overview

BA		RSE Standing timber	RSE Density	RSE BEF	above ground RSE	below-ground RSE	RSE above-ground + below-ground	RSE C content	RSE pursuant to C calculation	RSE dead wood
BWI I old German Länder	Ei	2,50%	19,78%	4,10%	20,35%	58,11%	21,55%	2,00%	21,65%	8,16%
	Bu	2,00%	13,66%	3,55%	13,96%	19,34%	11,74%	2,00%	11,91%	
	Alh	3,10%	15,02%	4,22%	15,58%	19,34%	12,63%	2,00%	12,78%	
	Aln	3,30%	8,71%	5,01%	10,19%	19,34%	9,07%	2,00%	9,28%	
	Fl	1,40%	18,83%	7,08%	19,56%	25,34%	16,36%	2,00%	16,49%	
	Ta	3,30%	22,65%	7,32%	23,33%	25,34%	18,82%	2,00%	18,93%	
	Dgl	6,00%	20,77%	9,63%	23,26%	25,34%	18,70%	2,00%	18,81%	
	Ki	2,00%	27,21%	3,16%	27,38%	25,34%	21,92%	2,00%	22,02%	
	Lä	3,70%	18,18%	2,22%	18,69%	25,34%	15,43%	2,00%	15,56%	
New German Länder	Estimate 1993									12,78%
BWI II old German Länder	Ei	2,24%	19,78%	4,10%	21,03%	59,17%	22,08%	2,00%	22,17%	7,70%
	Bu	1,96%	13,66%	3,47%	14,72%	19,07%	12,29%	2,00%	12,46%	
	Alh	2,61%	15,02%	4,37%	16,78%	19,07%	13,52%	2,00%	13,67%	
	Aln	2,94%	8,71%	5,10%	12,12%	19,07%	10,26%	2,00%	10,45%	
	Fl	1,59%	18,83%	7,16%	19,86%	25,45%	16,61%	2,00%	16,73%	
	Ta	3,76%	22,65%	7,70%	23,98%	25,45%	19,37%	2,00%	19,47%	
	Dgl	4,14%	20,77%	9,89%	24,76%	25,45%	20,00%	2,00%	20,10%	
	Ki	2,28%	27,21%	3,18%	27,79%	25,45%	22,29%	2,00%	22,38%	
	Lä	3,65%	18,18%	2,22%	20,05%	25,45%	16,41%	2,00%	16,53%	
BWI II new German Länder	Ei	4,31%	19,78%	4,10%	22,39%	59,17%	22,80%	2,00%	22,89%	10,08%
	Bu	4,23%	13,66%	3,41%	16,53%	19,07%	13,67%	2,00%	13,81%	
	Alh	4,85%	15,02%	4,37%	18,76%	19,07%	14,99%	2,00%	15,12%	
	Aln	3,84%	8,71%	4,94%	12,28%	19,07%	10,37%	2,00%	10,57%	
	Fl	3,48%	18,83%	7,06%	20,72%	25,45%	17,18%	2,00%	17,30%	
	Ta	40,40%	22,65%	7,49%	61,51%	25,45%	46,55%	2,00%	46,60%	
	Dgl	13,94%	20,77%	9,94%	26,80%	25,45%	21,48%	2,00%	21,57%	
	Ki	2,46%	27,21%	3,14%	31,37%	25,45%	25,14%	2,00%	25,22%	
	Lä	5,87%	18,18%	2,22%	20,49%	25,45%	16,83%	2,00%	16,95%	

14.5.1.1.2.2 Source-specific quality assurance / control and verification

The calculated data is based on ACCESS queries of Federal Forest Inventory data. With regard to the quality assurance developed for the Federal Forest Inventory, the reader's attention is called to the literature for the Federal Forest Inventory.

First, an estimate was carried out using the BURSCHEL et. al. (1993) method, to provide an indication of the orders of magnitude of the extrapolation. This estimate, which is based on aggregated values (average stocks, by tree-species groups), was carried out by two different persons, using two different methods (published BWI results and ACCESS queries). The results obtained with the two methods agreed.

In the individual-tree calculations, a "Burschel" scenario (cf. Annex 14.5.1.1.1.2.6) using the same basic densities used for the estimate (using aggregated values), was calculated. The resulting values agreed with the calculations using the aggregated values. Consequently, it is clear that the ACCESS queries, in general, provide correct values; on the other hand, their results can deviate depending on what assumptions are made for basic densities and root-shoot ratios.

One systematic error persists, however: It was not possible to estimate rejuvenation below the standing-timber threshold, and the relevant figure is not found in the stock data, because the volume-expansion function is based on standing-timber volumes. The lack of rejuvenation stocks results in a systematic underestimation of total stocks.

14.5.1.1.2.3 Source-specific recalculations

The 2002 Federal Forest Inventory II provided new random-sample data. For the old German Länder, this was a repeat inventory using the same random-sample points. As a result, it was possible to derive, from its data, the C-stock changes for these countries, with the "stock-change method". For the new German Länder, this was possible only to a limited extent, since only forest-establishment data is available for that region for 1993.

In addition, for the first time the calculation took account of underground biomass as well as above-ground biomass (cf. methods 14.5.1.1.1.1.2).

The "stock-change method" was applied for the new and old German Länder, and linearly interpolated and extrapolated for the relevant period.

The greenhouse-gas inventory for 2006 presents newly calculated data for all years since 1990. Time-series consistency is thus assured.

At the same time, reporting has been converted in keeping with the new CRF tables adopted at the 9^{th} Conference of the Parties in Milan.

Pursuant to this recalculation, stock increases are twice as high as listed in previous inventories. The main reason for this is the wood-stock increase determined in BWI II, an increase that far exceeds existing yield-table estimates. Other factors include inclusion, for the first time, of underground biomass, improved methods of calculation and, possibly, underestimation of the outset stocks in the new German Länder.

14.5.1.1.3 Land converted to Forest Land

14.5.1.1.3.1 Source-category description

Forest is created through succession, afforestation and reforestation; new forest areas begin storing C equivalents as soon as they are converted. In a rigorous approach, the C-stocks of previous land uses should be deducted. But no data is available on previous plant coverage (for example, individual trees, hedges or long-lived woody cultivations) and its biomass. Overall, such stocks are considered negligible, especially since the total area of new forest land is very small in comparison to the total forest area (old German Länder 2002: 121 kha to 7,694 kha).

14.5.1.1.3.2 Methodological issues

14.5.1.1.3.2.1 New forest land

Pursuant to IPCC GPG-LULUCF (2003), new forest lands must remain in the category "new forest lands" for 20 years. No land-use-change data that could support comparisons is available prior to BWI I. For the old German Länder, direct comparison between BWI I and BWI II makes it possible to separate new forest land and deforested land since 1987. The new forest lands occurring between BWI I (key year 1987) and BWI II (key year 2002), and amounting to 121.45 kha (not including the non-wooded ground) can be categorised as follows in keeping with their existing uses:

Table 159: New forest lands, old German Länder

Category	Area [kha]	Annual increase in area [kha/a]
Cropland and permanent cultivations	30,57	2,04
Permanent grassland	45,46	3,03
Wetlands	15,67	1,04
Settled areas	29,75	1,98

For derivation of area figures for the various years in question, it was assumed that new forest land increased linearly between BWI I and II. In the CRF tables, these area increases are shown beginning with the key year for BWI I (1987).

When these areas are considered in comparison to the entire forest area of the old German Länder, 7693.72 kha, then the increases seem marginal – 1.58% over 15 years (both figures not including non-wooded ground).

For the new German Länder, only the net forest-land increase between 1993 and 2002 can be determined; it amounts to 174.56 kha. This difference is considered the new forest land. Its annual rate of increase is 17.46 kha/a; the data does not permit any allocation into outset categories. The area increases were assumed to progress linearly between 1993 and 2002.

14.5.1.1.3.2.2 Biomass stocks, new forest land

For the old German Länder, an individual-tree calculation was carried out for the new forest land (cf. 14.5.1.1.1.2.6). The distribution of stocks by outset categories (Table160) is weighted by areas, however.

Table 160: Stocks, new forest lands, end of 2002

Outset category	Stocks [Gg C]
Cropland and permanent cultivations	922
Permanent grassland	1.372
Wetlands	473
Settled areas	897

For the new German Länder, assumptions had to be made relative to these figures. The area increase was seen solely as a net increase; for this reason, area losses are not considered. The area increases were assumed to progress linearly between 1993 and 2002. The wood stocks on this area must be considered to be only stocks of the 1st age class (0-20 years, BWI II, new German Länder). For determination of the stocks on these areas, the standing-timber stocks of tree-species groups of the 1st age class were converted into C stocks. The average C stocks in the biomass of these areas, as of the end of 2002, was assumed – due to its young age – to be half of the average C stocks of the 1st age class. This produces a value of 18.01 t C/ha, or total stocks of 3,144 Gg C, for these areas at the end of the 2002 vegetation period.

The biomass stocks at the end of the 2002 vegetation period correspond to the biomass stock increases throughout the entire period under consideration since 1987 (old German Länder) and 1993 (new German Länder), as long as any possible previous plant cover is ignored. These stock increases were weighted with the new forest areas produced in the relevant report years, and then they were linearly interpolated throughout the entire period under consideration.

14.5.1.1.3.2.3 Stocks in dead wood, debris and soils on new forest areas

In our latitudes, it takes decades for typical forests stocks to form in these compartments. The annual rates were considered negligible – also in light of the small size of the new forest area overall – and not taken into account in the greenhouse-gas inventory.

14.5.1.1.4 Forest Land converted to Other Land

14.5.1.1.4.1 Source-category description

Forest areas converted to other forms of land use are smaller overall than the new forest areas. At the same time, they had higher average biomass stocks prior to conversion. In conversion, such stocks are normally removed, and thus they are considered C emissions.

The C-stock losses from dead wood, debris and soil, and relevant emissions of other greenhouse gases, cannot be precisely determined. The CRF tables thus contain only the C losses from above-ground and underground biomass. The IEF derived from biomass losses, and from the areas achieved in each relevant year since 1987, decreased continuously from 1990 to 2003. This does not reflect any true trend, however; it results simply in that areas have not been listed separately only since 1987, and not for the past 20 years, as called for by the IPCC (2003). As a result, the area has increased in each report year.

In addition to biomass, C stocks in dead wood and debris, and part of the carbon in the soil, are lost in deforestation. Burning of biomass, in conversion of forest, as well as mineralisation processes occurring via plowing and turning of topsoil, can cause both CO_2 emissions and additional greenhouse-gas emissions.

14.5.1.1.4.2 Methodological issues

14.5.1.1.4.2.1 Deforested areas

The total deforested area in the old German Länder (not including non-wooded ground) is about half as large (67.33 kha and 4.49 kha/a) as the new forest area. The C emissions that must be assigned to these areas are higher, as a result of their stock accumulations, than C binding by new forest lands.

The corresponding figures for the new German Länder cannot be derived from the available data.

14.5.1.1.4.2.2 Stock losses on deforested land

In the old German Länder, individual-tree-based extrapolation was carried out for this category (cf. 14.5.1.1.1.1.2). The C emissions that must be assigned to these areas are higher, as a result of their stock accumulations, than C binding by new forest lands. All in all, total stocks of 4,035 Gg C were lost from biomass in this category. Applying linear interpolation, this corresponds to an annual loss of 269 Gg C. For the sake of simplicity, it was assumed that these C stocks are emitted into the atmosphere in the year in which they are converted.

As to C-stock losses from dead wood, debris and soil, only a first, very rough estimate, based on average stocks identified by the Federal Forest Inventory (BWI) and the soil-condition survey (BZE; BMELF 1997), can be provided. In this estimate, it was assumed that dead wood and the humus layer decompose completely, while about 30% of the C stocks in the uppermost 30 cm of the mineral soil are lost. The results are reported here as a memo item, but they have not been included in the CRF tables.

In light of the great variability, by area, of dead-wood, humus and soil stocks, these figures are subject to very large uncertainties. The total relevant emissions could be more precisely estimated by linking the BWI points affected by deforestation with soil maps or with the nearest BZE points.

Table 161: Losses from dead wood, humus layer and soil upon deforestation

Category	**Stocks [Mg C/ha]**	**Stock loss [Gg C]**
Dead wood	2,6	11,7
Humus layer	18,0	80,8
Mineral soil (0-30 cm)	62,2	83,8
Total	**82,8**	**176,3**

Stock losses from deforestation cannot be calculated for the new German Länder.

14.5.2 Cropland, grassland, other areas and land-use changes (5B/5C/5F)

14.5.2.1 Land-area distribution and allocation of usage categories

14.5.2.1.1 Data sources and their adaptation

The following official German statistics were used as sources:

1. Bodennutzungshaupterhebung (BOHE; main survey of soil use) 1991, 1999, 2001 (DESTATIS, Fachserie 3, Reihe 2.1.2, Jg. 1993; DESTATIS, Fachserie 3, Reihe 2.1.2, Jg. 2000; DESTATIS, 2003a)
2. Flächenerhebung nach Art der tatsächlichen Nutzung (FE; area survey by types of actual uses) 1993, 1997, 2001 (DESTATIS, Fachserie 3, Reihe 5.1, Jg. 1994, 2002a & 2003)
3. Verteilungsschlüssel Kreisreform 1998 (distribution key for 1998 district reform)

Agricultural areas and their usage categories were determined via BOHE and FE data. The basis for designation of areas and land-use categories consists of definitions for the usage-type key of the Working group of surveying administrations of the Länder of the Federal Republic of Germany (Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder der

Bundesrepublik Deutschland - AdV), in the "Directory of area-based usages in the property cadastre and their definitions" ("Verzeichnis der flächenbezogenen Nutzungsarten im Liegenschaftskataster und ihrer Begriffsbestimmungen" - AdV, 1991), and on the "Ground-cover nomenclature" ("Nomenklatur der Bodenbedeckungen") of the CORINE LAND COVER project (DESTATIS, 1989).

The agricultural area was divided into the following usage categories:

1. Cropland with annual crops (rye, summer and winter barley, oats, triticale, feed plants, silo corn, potatoes, sugar beets, non-food crops – especially winter rape)
2. Long-lived crops (Fruit crops, osiers, poplars, Christmas tree farms, nurseries)
3. Vineyards
4. (Permanent) grassland
5. Untilled land

These categories were used for calculation of carbon and biomass stocks, as well as of shifts of areas between the various usage categories. For the CRF, categories 1.-3. were combined into "cropland", while categories 4. and 5. were combined into "grassland".

In compilation of land-use data, problems arose that are due to the political development in Germany after 1989. Since German reunification did not take place until October 1990, the first standardised statistical survey of agricultural area and land use for all of Germany was not carried out until 1991; this is why land use in 1991 served as the basis for calculations. In addition, the administrative boundaries between districts were redrawn, especially in the new German Länder, as a result of reunification. As a result, data from BOHE 1999 was not comparable with that of BOHE 1991 – some districts had "disappeared", while some had been created and others had simply changed. To provide a basis for comparison, therefore, the district areas used in the 1991 main survey of soil use (Bodennutzungshaupterhebung) were "redrawn", with the district-distribution key for the 1998 district reform, and the pertinent land-use categories, in their relevant shares, were shifted and adapted as necessary.

Due to differences in survey principles, the absolute difference between the agricultural area shown in FE 1993 and that shown in BOHE 1991 amounts to 8.4 % (cf. Chapter 14.5.2.6.1). To compensate for this, the BOHE area sum was proportionally related to the entire agricultural area shown by FE (this was adjusted via removal of bogs and heaths which by definition are uncultivated land), since FE, as a cadastre survey, shows the actual areas involved, by types of uses. The adjustment was made under the assumption that distribution of land-use classes and of soil units on the approximately 10 % of the area that was "missing" would correspond to that of the remaining area. Since BOHE 2001 was only a representative survey (100,000 farms) – i.e. not a complete survey – it provided no area data on vineyards and untilled land at the district level. This data was estimated, for the various districts, on the basis of the Länder data. It was assumed that the pertinent areas, in all districts, had changed in proportion to the Länder total. In each case, the reference basis consisted of the values from 1999. The changes were very small. In another complication, the BOHE data has been available in computerised form only since 1999, and the computerised differs, in format and extent, from the corresponding printed data. Consequently, extensive manual data collection and conversions had to be carried out in order to produce a usable, standardised set of data.

To obtain the entire agricultural area for the pertinent years, the areas for the various use categories of BOHE 1991 and 1999 were adapted, proportionally, to Germany's total area in

2001. This norming was necessary, since the FE of 1993, 1997 and 2001 differ in their figures for Germany's total area.

14.5.2.1.2 Determination of land-use changes, and of use-related area shifts

The data made it possible to determine the net changes in use categories for the periods 1991 – 1999 and 1999 – 2001. More current data is not yet available (can be provided by DESTATIS not earlier than August/September 2006). The area increases and decreases within the five categories were determined, at the district level, by subtracting areas from their corresponding areas at the relevant subsequent date.

This "net" consideration does not show land-use changes on individual areas, however. Since no records of such changes are kept in Germany, Gensior/Heinemeyer developed a procedure for estimating land-use changes. From a range of assumptions and prerequisites (including legal stipulations), they derived basic assumptions and a priority list. They then translated this list into an algorithm that describes a very "probable" direction of area shifting. The algorithm was incorporated into a computer programme that makes the allocation procedure fully transparent and always consistent.

Basic assumptions:

1. Emerging differences are always compensated for first within the agricultural area
2. Category amounts, in keeping with the priority list, are compensated for within the agricultural area until one of the two categories reaches an amount of zero.
3. When the "area changes" exceed the "ability of agriculture to compensate", the supernumerous land areas are shifted into the pool of the remaining district area (settlement and transport, water…).
4. When the "area changes" are smaller than the "ability of agriculture to compensate", land area is shifted from the pool of the remaining district area and into the pool of the agricultural usage category that had shown a deficit following the algorithmic run.

When no differences between the years under consideration emerge, no changes have occurred in the relevant (or in all) categories and in the pools subject to reporting obligations.

The pool serves as a reservoir for compensation, and it appears only in the sum of all districts; it contains the summed relevant remaining areas for the Federal Republic of Germany ("settlement and transport area", "forest area", "water area" and "areas with other uses", pursuant to FE). This approach in keeping with the survey principle used for the BOHE (farm-operation principle). For example, when an agricultural area category in a district grows or shrinks simply as a result of the survey principle being applied, the pertinent difference can be compensated for nationally from the pool, since Germany's total area does not change. The following example illustrates this principle: A farmer with a farm in the Braunschweig district leased and worked 100 ha of cropland in the Magdeburg district in 1991 (the area in question is counted with the Braunschweig district); in 1999, the pertinent land is again being worked by the owner, whose farm operation is located in Magdeburg (the area is counted with the Magdeburg district). In this case, it is assumed that the previous use is being continued, without any changes.

Where areas enter the pool, it is also assumed that the relevant land-use changes do not lead to any reduction of the carbon stocks in the soil or in the biomass in question.

In the authors' opinion, the following priority list (Table162) is based on the most probable directions of usage changes, based on assumptions and legal provisions. The following considerations are applied to vineyards, for example: Vineyards that are abandoned are usually located in steep, terraced areas that are difficult to work. Such land is thus most likely to lie fallow. According to legal provisions, such areas must be completely vacated. Normally, every other row between vine rows is covered with grass. After the vines have been removed, grass will also grow in their place.

Logically, therefore, the programme processes "vineyards" first. The area lost is always allocated to fallow land. The vines' biomass is lost completely, and discontinuation of cultivation enables the soil to add carbon on every second row.

Table 162: Priority list, use changes

Priority list					
Vineyards (R)	Decrease	R → B			
	Increase	B → R			
Permanent cultivations (D)	Decrease	D → B	D → A	D → G	
	Increase	B → D	A → D	G → D	
Grassland (G)	Decrease	G → A	G → D	G → B	
	Increase	A → G	D → G	B → G	
Cropland (A)	Decrease	A → B	A → G	A → D	
	Increase	G → A	B → A	D → A	
Fallow land (B)	Decrease	B → R	B → D	B → A	B → G
	Increase	R → B	D → B	A → B	G → B
Surplus		D/A/G/B → Pool			
Deficit		Pool → D/A/G/B			

Areas that change from forest to agriculture, or change vice-versa, have been identified via the Federal Forest Inventory data (cf. Chapter 7.1). These areas will be included in the calculation only after all district results have been summed. Following use of the above-mentioned algorithm, forest areas are part of the "pool". For this reason, the forest areas are removed from the "original" pool area (in cases of usage changes from agriculture to forest) or are offset with the pool areas in the various categories (usage changes from forest to agriculture).

The thus-determined areas were entered into the relevant columns of CRF tables 5A, 5B and 5C. Since "wetlands" and "settlement areas" are not reported and differentiated, the excess agricultural area is listed completely in Table 5 F, and additions to the agricultural area are shown, in Tables 5B and 5C, in the line "Other Land converted to…".

14.5.2.1.3 Organic soil area

Since agriculturally used organic soils are not listed separately in statistical surveys (they are subsumed under the relevant usage categories (BOHE) or under agriculture (FE)), such areas (fens and raised bogs (lead-soil associations (Leitbodenassoziation) 6 and 7 (BUEK 1000)), and the relevant usage categories, were determined via the soil overview map drawn to a scale of 1 : 1,000,000 (BUEK 1000) and via CORINE – Landcover (cf. Chapter 14.5.2.2). Via their area ratios to other soil types, at the district and national levels, the bog areas were proportionally allocated to the agricultural areas shown by BOHE 1991/1999. In the CRF tables, they appear subsumed within the columns for the relevant usage categories.

14.5.2.2 Determination of carbon stocks and their changes as a result of land-use changes

Data on spatial distribution of soil communities in Germany is available in the form of a digital soil map on a scale of 1: 1 000 000 (BUEK 1000). The soil map has been prepared via proportionate allocation of discrete profile data (obtained at individual points in the landscape) on land units (polygons) within the map area. The profiles provide quantitative information on a range of key factors measured. This information provided the basis for estimating the carbon stocks in agricultural soils. Calculation was carried out using the map's/legend's data for the lead profiles of the 72 lead soil units, data that included specific C_{org} content measurements, humus, raw-density and skeleton classes and profile and horizon descriptions. With this data, and under the assumption that the map's values, in each case, are representative of the entire relevant legend/map unit, C_{org} stocks were calculated. To this end, the C_{org} content figures were multiplied by the relevant raw densities and horizon depths and the relevant skeleton portions were deducted. The horizon stocks were added to a depth of 30 cm. The range of carbon stocks was determined via the figures in the relevant legend/map unit pursuant to KA 4 (ARBEITSGRUPPE BODEN, 1994). In each case, the aforementioned algorithm was used to calculate a minimum value (lowest possible C_{ORG} content for the class, lowest possible storage density, maximum skeleton content) and a maximum value (highest possible C_{ORG} content for the class, highest possible storage density, minimum skeleton content).

A geo-information system (GIS) was used to assign the individual soil units to rural districts and to the relevant land-use units. BUEK 1000 was overlaid with polygons of district boundaries and with the CORINE Landcover land-use classes. For each of the resulting polygons, carbon stocks were calculated to a depth of 30 cm and then summed, in keeping with land use (farmland, grassland, heterogeneously structures agricultural land), at the district level. Division by the area sum then produced a weighted carbon-stock figure (and minimum and maximum values) – relative to soil unit and expressed in t/ha * 30 cm – for each land-use class, at the district level; for the sake of comparison, stocks were summed at both the district and national levels. The CORINE nomenclature was translated as follows into the usage-type key of AdV (1991):

Cropland → Cropland

Grassland → Grassland

Agricultural land with heterogenous structure → Garden land + fallow land

Since the forest-conversion areas for Germany were available only in aggregated form, specific carbon stocks, averaged over all districts and soil types, were assumed for these soils.

14.5.2.3 Changes in carbon stocks in the soil and in biomass

14.5.2.3.1 Derivation of EF for mineral soil as a result of land-use changes

The emission factors for changes in carbon stocks in the soil, resulting from use changes, were drawn from the literature. To this end, a number of studies, including several reviews, were evaluated. From these studies, those studies were selected that directly considered carbon stocks following land-use changes, or whose data permitted relevant derivation. Of these studies, in turn, only those were used for EF derivation that apply criteria, for soil, climate and other parameters (for example, about 30 cm soil depth) that are at least somewhat comparable to those required for German reporting (ANKEN et al., 2004; BLANK & FORSBERG, 1989; BOUMA & HOLE, 1971; BOWMAN et al., 1990; BURKE et al., 1995; BUYANOVSKY ET AL., 1987; CAMBARDELLA & ELLIOT, 1992 & 1993; CAMPBELL et al.,1989; CHAN AND MEAD, 1988; CONANT et al., 2001; DAVIDSON & ACKERMANN, 1993; DEGRYZE et al., 2004; FRANZLUEBBERS et al., 1999; FRANZLUEBBERS et al., 2000; GEBHART et al.,1994; GUO & GIFFORD, 2002; HART et al., 1988; HORNE et al., 1992; IHORI et al., 1995; JASTROW & LUSSENHOP, 1998; LARIONOVA et al., 2003; LAWS & EVANS, 1949; LIEBIG et al., 2004; MANN, 1986; MARTENS et al., 2003; MURTY et al., 2002; POST & KWON, 2000; POTTER et al., 1999; REEDER et al., 1998; ROSS AND HUGHES, 1985; SKEMSTAD et al., 1994; TIESSEN et al., 1982; VORNEY et al., 1981; etc.).

In spite of the wide distribution of absolute results it shows, the literature review supports the oft-heard assumption that conversion of grassland to cropland leads to losses of soil carbon stocks, and that conversion of cropland to grassland enriches soil carbon stocks. Nonetheless, results can be adduced that support the opposite assumption. The breadth of the spectrum of results complicates evaluation, although very close relationships can be found via simple or multiple regression ($r^2 > 0.9$). The results that are produced in this manner, however, show little plausibility and always include 0 within their 95 % confidence intervals.

For this reason, the annual carbon losses and additions, measured in percent of original stocks, and calculated via the difference between outset and final stocks and via the duration of the relevant study, were compared to the relevant values for the overall study duration, in order to obtain annual loss percentages, as a function of study duration and total loss from, or additions to, the original stocks. The relevant data is shown in Figure74 and Figure75.

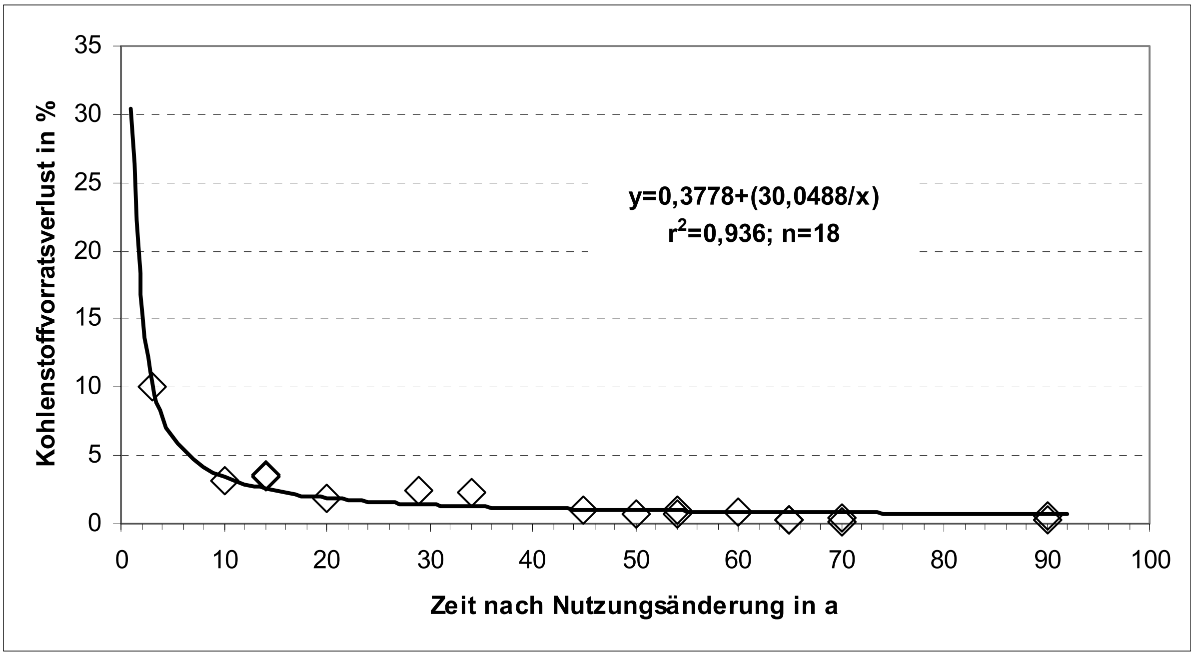


Figure 74 Relationship between annual losses from outset carbon stocks (in percent) and study duration following land-use changes (grassland, permanent cultivations, fallow land or forest to cropland (annual crops))[96]

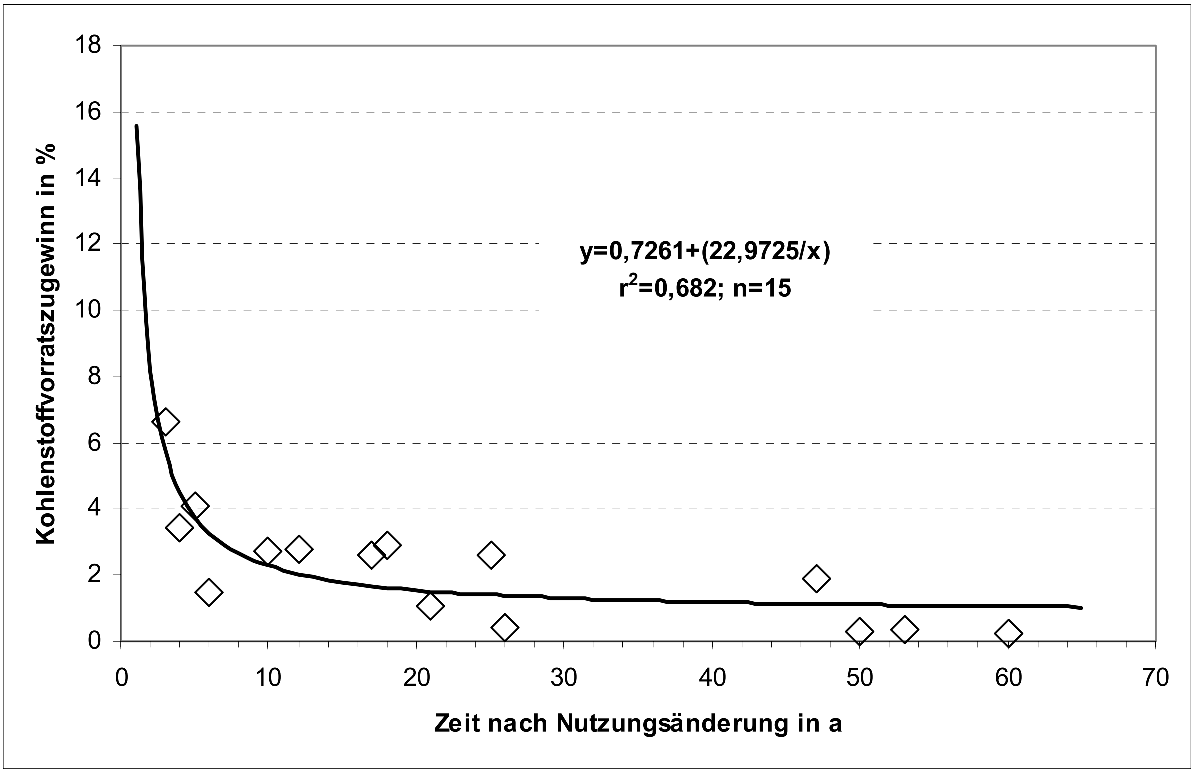


Figure 75 Relationship between annual additions to outset carbon stocks (in percent) and study duration following land-use changes (cropland (annual crops) to grassland, permanent cultivations, fallow land or forest).[96]

The highly significant inverse functions show that the largest changes in carbon stocks resulting from land-use changes occur in the first years – and mostly in the first year – following the land-use changes. This means that in subsequent years changes in soil

[96] Translation: vertical: Carbon-stock losses [%]; horizontal: Time after use change [a]

cropland are small in comparison to those of the first year. This applies both to carbon losses (normally, from conversion of cropland to grassland) and to carbon additions (normally, grassland to cropland). In the first year, however, losses are almost twice as high as additions. These results, along with other calculations (using multiple regression) also show that changes in carbon stocks, in respect to 20-year periods, and after the first year, amount to only about 5 % of the original stocks in the case of additions, and to only about 1% in the case of losses.

This implies that the time period specified by IPCC GPG LULUCF (2003) as a basis for calculation of additions and losses is too long in the case of losses and much too short in the case of additions. The contribution from stock changes is thus applied in the first year following the relevant land-use change, and it is applied only once, for the year in which it is determined. As a result, German reporting does not include the floating average for 20 years (pursuant to IPCC, 2003); the average does not seem relevant, for technical reasons, and unreasonable effort would be required to obtain the necessary high degree of spatial disaggregation of changes over 20 years. Apart from these considerations, usage changes in agriculture tend to take place in the short-to-medium term, so that further changes prior to establishment of the "final balance" may be assumed (cf. Chapter 14.5.2.6.1), and thus the procedure approximates the real situation, considered generally.

With the stipulation that stock changes are allocated only once, for the year in which they are determined (x=1), the formulae shown in Figure75 and Figure75 thus yield the following emission factors for soil carbon:

Cropland to grassland / forest / fallow land:	15.5554 % (original stocks *1.155554)
Cropland to permanent cultivations:	15.5554 % (original stocks * 1.155554)
Vineyards to fallow land:	7.777 % (original stocks * 1.07777)
Fallow land to vineyards:	-15.2133 % (original stocks * 0.847867)
Grassland / forest / fallow land to cropland:	-30.4266 %(original stocks * 0.695734)

For vineyards, the above factors result from the fact that normally every other row between vine rows is allowed to have a grass cover. For conversion of grassland to permanent cultivations and vice-versa, no changes in soil carbon stocks are assumed, since permanent cultivations normally have a grass cover. Since no nation-wide data is available on tilling of grassland, this aspect is excluded from the inventory.

14.5.2.3.2 Derivation of calculation figures (emission factors) for biomass

14.5.2.3.2.1 Permanent cultivations, fruit plantations and vineyards:

The default factor from IPCC GPG-LULUCF (2003) was used as a basis for estimating the biomass.

14.5.2.3.2.2 Grassland and non-perennial crops:

Emission factors for carbon stocks in above-ground biomass of grassland and non-perennial crops were derived on the basis of results of the 1999 main survey on soil use (Bodennutzungshaupterhebung) and of figures from the literature. The calculation was carried out at the district level for wheat, rye, winter barley, summer barley, oats, triticale, silo corn, feed plants, potatoes, sugar beets, non-food crops (primarily rape) and grass. The figures for the areas under cultivation with the various relevant crops (ha), and those for harvests (t/ha), were taken from the 1999 main survey of soil use (Bodennutzungshaupterhebung; DESTATIS, 2000 & 2003). In some instances, harvest data for individual districts was lacking. In such cases, the data was replaced with average annual values for Germany, drawn from the Statistical Yearbook (Statistisches Jahrbuch (Tab. 105, BMVEL, 2003). The biomass, in t/district, was obtained by multiplying the area under cultivation with the applicable harvests. The harvest figures given by the main survey of soil uses (BOHE) were adjusted to take account of residual moisture content. For grain, a residual moisture content of 14 % was assumed. The corresponding figures for other crops were as follows: silo corn, 28%; potatoes, 78 %; and sugar beets, 77 %.

Biomass consisting of straw, leaves and stems was calculated with factors and dimensioned figures from harvests of grain, potatoes, sugar beets and rape. These were averaged from figures given in the literature:

Factors:

Straw production:	Wheat:	1,2
	Rye:	1,7
	Winter barley:	1,05
	Summer barley:	1,05
	Oats:	1,4
	Triticale:	1,7 (value for rye)
	Rape:	1,9

Dimensioned figures

Stems and foliage:	Potatoes:	0,4	t/ha
Leaves:	Sugar beets:	0,8	t/ha

Source: Die Landwirtschaft 1998; FISCHER 1988; OEHMICHEN 1990; RUHR-STICKSTOFF AG 1985

Grassland biomass was determination by multiplying the area under cultivation by the following average yields:

Grass:	8,46	t/ha	(BMVEL 2003)
Feed plants:	8,83	t/ha	(BMVEL 2003)

For calculation of biomass carbon stocks, average carbon stocks of 45 % were assumed (carbon content of individual plant parts and types 37 – 60 %, whole plants 44 – 48 % (OSOWSKI et al., 2004)). The sum of all parameters yiels the carbon stocks for above-ground biomass on agricultural land, at the district level. From these stocks, and the arable agricultural land, a rural-district-specific, average value for biomass carbon stocks was determined (in t/ha). As $EF_{initial}$ (cf. Chapter 7.2.2.4), this value then serves as a basis for all other calculations in connection with land-use changes. Biomass calculations were carried out pursuant to IPCC GPG LULUCF (2003).

14.5.2.4 Liming

The annual figures for liming were taken from official statistics (DESTATIS, Fachserie 4, Reihe 8.2). The methods by which they were obtained are described in DÄMMGEN et al.

2004. The emissions are derived from figures for product sales. Because companies have a statutory duty to supply information, the data collection is complete. The data does not provide direct information on the annual use of fertilizers in agriculture and forestry. For this reason, figures cannot be differentiated with regard to types of application (dolomite or lime) or to the spreading sites (cropland or grassland). Differences can occur between amounts sold and amounts actually used:

- due to changes in commercial stocks
- due to use of fertiliser outside of agriculture and forestry, e.g. on private land, gardens, sports facilities.

14.5.2.5 Determination of N2O emissions following conversion to cropland

N_2O emissions following conversion from other forms of use to cropland were determined pursuant to IPPC-GPG (2003). For this purpose, area weighted nitrogen stocks were calculated, in line with the area-weighted carbon stocks per district (see Chapter 14.5.2.2). From these two parameters, in turn, weighted C/N ratios were determined. The original data were taken from BUEK 1000 (BGR). Using these C/N ratios, changes in the nitrogen stock were calculated, in the categories “permanent cultivations to cropland”, “grassland to cropland”, “forest to cropland” and “fallow land to cropland”, from the carbon-stock changes resulting from the execution of the distribution programme (cf. Chapter 14.5.2.1.2) and the application of the relevant emission factors (cf. Chapter 14.5.2.3). They were then set against the default value of 0.0125 t N_2O-N/t N, and N_2O emissions were thus determined.

14.5.2.6 Uncertainties

14.5.2.6.1 Area designation

The land-use categories required for allocating soil types, cropland, grassland and heterogeneously structured agricultural land, were taken from the CORINE Landcover data. The area values differ, in absolute terms, from those of the area survey (Flächenerhebung, FE) and those of the main survey of soil use (Bodennutzungshaupterhebung, BOHE). With respect to the 1993 area survey, the agricultural area is estimated to be about 11 % larger; with regard to the 1991 main survey of soil use, it is estimated to be about 21 % larger (GENSIOR, 2004). The CORINE data’s grassland to cropland ratio, as compared to that shown by the main survey of soil use, has remained relatively constant in the various rural districts, however: the mean deviation is 6.6 %; this means that main survey of soil use overestimates the relative cropland area, with respect to the agricultural area, while it underestimates the grassland area GENSIOR, 2004).

The absolute difference between the agricultural area in the 1993 area survey and the agricultural area in the 1991 main survey of soil use is 8.4 %. The reasons for this difference include:

- The survey principle (operational principle (BOHE), usage principle (FE))
- The time lag between the surveys (2 years)
- Differences in definitions
- The intervals at which the cadastre areas are updated and, especially
- The cut-off boundaries (pursuant to the amended Agricultural Statistics Act (Agrarstatistikgesetz – Federal Law Gazette 1992), farms are exempted from BOHE if they have fewer than a certain minimum number of animals or if they have less than 2 ha of land).

Studies of ERHARD et al. (2002) have shown that, as a result, the agricultural area identified in the main survey of soil use is some 10 % smaller than the agricultural area identified in the FE. It is assumed that distribution of any district's remaining area corresponds to the distribution in the rest of the district, and that the remaining area cannot exceed 10 % of the district area. Via harmonisation of BOHE values with FE values, the error from this assumption cannot exceed the same level.

To estimate the error resulting from calculation of land-use changes from net data of the modified BOHE, the data on which the NIR is based, for the Gifhorn rural district, was compared with that from a study showing the results of a "satellite-imaging analysis of land-use changes, illustrated with the example of grassland use in the Gifhorn rural district" (LAGGNER, 2003).

The net data from evaluation of the satellite imagery, and the net BOHE data, both show a decrease of grassland and cropland areas between 1991 and 2001, along with an increase in fallow areas. Consideration of the net differences shows that the satellite data and the BOHE data differ only slightly with regard to cropland and grassland (cropland: 782 ha (sat.) to 658 ha (BOHEmod.); grassland: 4,622 ha (sat.) to 2,677 ha (BOHEmod.). The larger difference for the satellite imagery in the area of grassland is due to inadequate identification of grassland in the 1991 evaluation (LAGGNER, 2003)).

Differentiation of this data, with application of the aforementioned model for conversion of grassland to cropland, yields 136 ha, and 9,152 ha for the satellite imagery (ATKIS, about 4,600 ha). For conversion of cropland to grassland the model calculation yields a value of 0 ha, while evaluation of the satellite imagery yields 6,278 ha (ATKIS, about 8,500 ha).

It becomes clear that consideration of summed data fails to take account of the majority of actual changes. As a result, the error for estimation of area shifts can be enormous and, consequently, the error in estimation of changes in carbon stocks can also be enormous. In the present case, with regard to cropland to grassland, and vice-versa, it amounts to about 6,000 – 7,000 %. This means that land-use changes are being underestimated by a factor of at least 60 – 70. In actuality, the discrepancy is likely to be even larger, since the work of LAGGNER (2003) evaluated the period 1991 – 2001 without any intermediate stages. Inclusion of an image for 1984 increases the factor to 100. Further investigations for other districts using GIS-based methods underline this; here too, summed orders of magnitude are roughly correct, but fluctuations between the various assessment dates are not taken into account. These ATKIS-based tests also revealed errors up to the factors indicated above.

It is highly unlikely that changes in carbon stocks vary to the same degree, since a "state of balance", in keeping with usage conditions, has likely been attained on these areas over centuries of agricultural use (further studies in this area are urgently required!). Nonetheless, it is clear that the CRF tables' figures for changes in carbon stocks in mineral soils, as a result of land-use changes, tend to be underestimations. The example shows that:

- Land-use changes can be identified precisely only with the use of spatial references (for example, InVeKoS data, remote sensing, ATKIS, ALKIS)
- Changes in soil carbon stocks can be reliably determined only via inventories. Calculation, using complex models, would be possible only after a basic understanding has been gained of the processes and "states of balance" involved in C and N turnover. Such calculation would, however, require appropriate calibration and validation.

14.5.2.6.2 Soil

The provisional C_{org}-stock estimates for agriculture are based on the only existing complete-coverage soil map for all of Germany, which is drawn to a scale of 1: 1,000.000 (BUEK 1000). This map integrates soil information over large areas and aggregates indexes within classes. Consequently, the scattering for data on changes in carbon stocks, as estimated from these figures, is very wide. The potential error for changes in carbon stocks is 70 % of the average.

The curve corrections for determining emission factors (Figure74 and Figure75) are highly significant; they explain 93.6 % and 68.2 %, respectively, of the variance. For grassland / forest / fallow land to cropland, the standard error for the estimate is 0.6 $\%*a^{-1}$ of the original carbon stocks; for cropland to grassland / forest / fallow land, it amounts to 1.01 $\%*a^{-1}$.

14.5.2.7 Planned improvements

The data required for reporting for the Framework Convention on Climate Change is not yet fully available, and access to existing data in the manner desired (regularly, of constant quality, within a reliable legal framework) is also not yet assured.

14.6 Other detailed methodological descriptions for the source/sink category Waste and Wastewater (6)

14.6.1 Waste (6.A)

14.6.1.1 Uncertainties for the source category "solid waste disposal on land""

The following uncertainties were estimated by the responsible Federal Environmental Agency expert on 23 February 2004. The uncertainties must be considered provisional for the time being, since no national experience has yet been gained with the FOD method. In addition, an effort is being made to hold an expert hearing that will adjust the estimated uncertainties as necessary, thereby placing them on a broader, more reliable basis.

Table 137: Estimated uncertainties for waste landfilling

	Definition of time series						Uncertainties data					
		Source description					Base year 1990 [4]		2002			
No.	CRF	For example, module name or suitable aggregate within the listed CRF code [1]	Further source differentiation if applicable[2]	CSE time series ID if applicable	Value type (EF / EM / AR)	If EF / EM: Gas	Uncertainty [+/-%] [3]	Distribution type [5]	Uncertainty [+/-%] [3]	Distribution type [5]	Remarks on considerations, literature sources, etc.	Estimated by
1	6A1	Waste landfilling			MSW_T (x)							
2	6A1	Waste landfilling			MSW_F(x)		+/-5%	N	+/-2%	N	For 1990: low reliability in ABL, no data for NBL	
3	6A1	Waste landfilling			DOC(x)	CH4	+/-20%	N	+/-20%	N	No reliable results from studies of raw waste in MB-waste-treatment facilities	
4	6A1	Waste landfilling			DOC_F	CH4	+/-30%	N	+/-30%	N		
5	6A1	Waste landfilling			MCF(x) (bei MCF=1)	CH4	+ 0% -10%	L	+0% -10%	L	Pursuant to IPCC-GPG	
6	6A1	Waste landfilling			F	CH4	+10% -0%	L	+10% -0%	L		
7	6A1	Waste landfilling			k	CH4	+50% -35%	L	+50% -35%	L		
8	6A1	Waste landfilling			R(t)	CH4	+/-10%	N	+/-10%	N	Pursuant to IPCC-GPG, low with respect to other uncertainties	
9	6A1	Waste landfilling			OX	CH4	+50% -35%	L	+50% -35%	L	Corresponds to half-life of 3.5 years (k=0.23) to 8 years (k=0.09)	

[1] If the CSE module name and CSE time-series ID are not available for estimation, or are too detailed, the sources may also be defined via CRF, and another unambiguous description, in the field "further source differentiation".
[2] Pursuant to CSE dimensions, if required for differentiation: e.g. fuel, type of operation, material, equipment, measure
[3] With log-normal distribution: [+x%; -y%]
[4] For F gases, the base year is 1995.
[5] Distribution types: N (normal distribution); L (log-normal distribution); T (triangular); U (uniform)

14.6.2 Wastewater (6.B) – Data for determination of emission factors for wastewater and sewage-sludge treatment (6.B.2)

Under the IPCC method, percentage levels of aerobic and anaerobic wastewater and sewage-sludge treatment should be determined via characterisation of wastewater and sewage-sludge treatment systems at the national level.

Evaluation of national inventory reports shows that the various Länder have used widely differing approaches to determine their Länder-specific emission factors. In some countries, the available data is not adequate to permit direct use of the IPCC method, and thus such countries have used alternative calculation methods or aggregated values. The evaluation reveals the following:

- A few countries list specific methane conversion factors for national treatment systems (Czech Republic, U.S., Finland; cf. Table 138). In addition, sub-categorisation of wastewater systems is not standardised.
- In some countries, it is assumed that wastewater treatment normally occurs, either aerobically or anaerobically, in closed systems with methane collection, but that small quantities of methane can still escape in exceptional situations. In such cases, very low MCF are chosen for treatment of municipal wastewater (Finland, Czech Republic).
- The UK uses a national method based on characterisation of sludge-treatment processes.
- In some countries, emission factors are determined not via organic load, percentage level of anaerobic treatment and MCF – as called for by the IPCC – but via population equivalents (Canada, Austria, Germany).
- Only Austria explicitly differentiates its emission factors by mechanical, biological and other treatment.

Table 138: Reported methane conversion factors in national inventory reports

MCF	Czech Republic	Finland	U.S.
Management of household and commercial wastewater		0.025	0.05
aerobically treated municipal wastewater	0.05		
anaerobically treated municipal wastewater	0.5		
on-site treatment	0.15		
untreated household and commercial wastewater discharge into rivers	0.05		
septic tanks			0.5
Industrial wastewater treatment		0.01	
aerobically treated industrial wastewater	0.06		
anaerobically treated industrial wastewater	0.7		
untreated industrial wastewater	0.05		
differs by sector			0.05 - 0.77
Sludge treatment			
aerobic treatment of sludge from municipal wastewater	0.1		
anaerobic treatment of sludge from municipal wastewater	0.5		
aerobic treatment of sludge from industrial wastewater	0.1		
anaerobic treatment of sludge from industrial wastewater	0.3		

Source: National inventory reports

Further information on determination of methane emissions from wastewater and sewage-sludge treatment of other countries is provided by (ÖKO-INSTITUT, 2004b).

14.6.3 Determination of nitrous oxide emissions from wastewater treatment (6.B.2)

The IPCC Guidelines describe a method for estimating nitrous oxide emissions from wastewater treatment (IPCC, 1996a: Chapter 6.5). An evaluation of experience gained by other countries (further information in ÖKO-INSTITUT, 2004b) shows that all countries that determine nitrous oxide emissions from wastewater treatment either use the IPCC method or made country-specific adjustments to the IPCC method:

- One exception is Belgium, which determines emissions on the basis of the EMEP/CORINAIR manual.
- Some countries also determine nitrous oxide emissions from industrial wastewater, although the IPCC does not describe any method for this (Austria, New Zealand, Sweden and, in future, U.S.).
- The most important relevant country-specific adjustments include consideration of industrial wastewater (see above), determination of nitrogen loads in wastewater-treatment systems instead of determination of daily human protein intake (Sweden) and consideration of other nitrogen sources in municipal wastewater (U.S.).
- In those countries in which nitrous oxide emissions are determined, inter alia, via nitrogen fractions in protein, the IPCC default value is used.
- All countries use the IPCC default value in cases in which the emission factor (kg N_2O-N/kg wastewater N) is relevant for determination of nitrous oxide emissions.
- Data on average per-capita protein intake comes either from national studies and data (UK, Australia) or from the FAO database (U.S., Austria, etc.); such data varies widely. The protein intake for the UK, which was determined via a national survey, is much lower than the others; this is due to the method by which the average value was determined. Table 139 lists average daily protein intake, along with the pertinent data source, for those countries that list this data item explicitly in their national inventory reports.

Table 139: Average daily and annual protein intake

Country	Protein [kg/person & year]	Protein [kg/person & day]	Data source
UK	8.65	0.024	National Food Survey (DEFRA, 2001). The data is based on a survey of food consumption at home and thus is likely to be a low estimate.
Australia	36.28	0.099	Australian Institute of Health and Welfare (de Looper and Bhatia
USA	41 (1996)	0.112	FAO database
	41 x1.75	0.197	Adjustment via comprehensive method
Sweden	32.85	0.090	National data
Canada	40.15	0.110	No data source listed
Germany	34.68	0.095	FAO database (average, 1990-2001)
New Zealand	4.75	0.013	With respect to nitrogen in wastewater
Belgium			FAO database
Czech Republic	25.00	0.068	No data source listed

Source: National inventory reports

15 ANNEX 4: CO_2 REFERENCE APPROACH AND COMPARISON WITH THE SECTORAL APPROACH, AND RELEVANT INFORMATION ON THE NATIONAL ENERGY BALANCE

Information on the CO_2 reference approach, a comparison with the sectoral approach and relevant information on the national Energy Balance are found in Chapter 3.1.5.5.

16 ANNEX 5: ASSESSMENT OF COMPLETENESS, AND ASSESSMENT OF POTENTIALLY EXCLUDED SOURCES AND SINKS OF GREENHOUSE GAS EMISSIONS

To date, no detailed information is available on assessment of completeness and of potentially excluded sources and sinks of greenhouse-gas emissions.

17 ANNEX 6: ADDITIONAL INFORMATION TO BE CONSIDERED AS PART OF THE NIR SUBMISSION (WHERE RELEVANT) OR OTHER USEFUL REFERENCE INFORMATION

17.1 German National System of Emissions Inventories

Artcle 5.1 of the Kyoto Protocol mandates the establishment of National Systems for preparation of greenhouse-gas emissions inventories. Under this provision, industrialised countries (Annex I Countries) commit themselves to installing, by no later than 2007, **National Systems** that support determination of greenhouse-gas emissions from sources and greenhouse-gas emissions removals via sinks. Via the *Decision of the European Parliament and the Council on a system for monitoring of greenhouse-gas emissions in the Community and for implementation of the Kyoto Protocol of 11 February 2004*, Germany is also obligated to prepare **national inventory systems** under the Kyoto Protocol, with this process to begin no later than 31 December 2005.

17.1.1 Tasks of the National System

The purpose of the National System is to ensure, by means of continual quality management and ongoing inventory improvement, that the methodological provisions of the IPCC guidelines and the GPG are extensively applied. It comprises all institutional, legal and procedural facilities and agreements to be reached and established in Annex 1 countries of the Framework Convention on Climate for emissions calculation reporting and for archiving of all relevant inventory information.

As a result, in preparation of emissions inventories, a National System must involve all those institutions and resources of the relevant country that are able to make highly competent contributions to such inventories. Such efforts include the following tasks:

- Establishment of a national agency for coordinating emissions reporting[97]
- Specification / documentation of institutional facilities, legal agreements and procedures on emissions calculation and reporting
- Archiving of all inventory information
- Initiation of measures for improving emissions inventories

Extensive organisational scope is granted to the Parties for the concrete institutionalisation of the National System. Figure 71 presents a schematic overview of the functions that must be provided and of the institutions to be involved in implementing the National System.

97 The coordinating agency (single national entity – SNE) is charged with serving as the central point of contact for all participants in the National System. It is required to provide a framework for transparent, consistent, complete, comparable and precise inventories.

The National System

In preparation of emissions inventories, the National System should involve all of the state's institutions that can make highly competent contributions to such inventories.

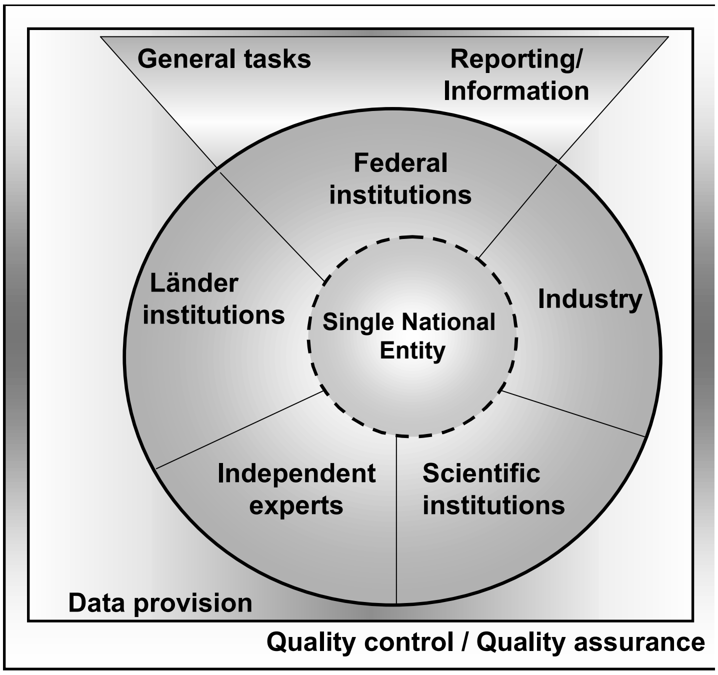


Figure 71: Functions of the National System and the institutions to be involved

17.1.2 Development of the National System

The ***Coordination Agency for the National System (Single National Entity)*** is sited in the Federal Environmental Agency's Section I 4.6. It acts as a central point of contact, and it coordinates and informs all participants in the National System. During the 2003-2005 period, the Single National Entity has given priority to developing new data sources and to identifying institutions and organisations that need to be added to the National System. Other key tasks have included introducing the Quality System for Emissions Inventories and facilitating the institutionalisation of the National System (sharing in work on the draft of the Act on climate-protection statistics (Klimaschutzstatistikgesetz), and drafting a standard text for agreements between the Single National Entity and relevant non-governmental organisations).

17.1.3 Workshop on the National System

In November 2004, the Federal Environmental Agency held a workshop on the National System of Emissions Inventories. At this workshop, participants were informed about the status of emissions reporting on greenhouse gases, as well as about relevant requirements. The event also discussed existing problems and weaknesses, and it developed and identified approaches for improving inventories and inventory reporting and for solving relevant problems. The event topics included methods in various areas and for various source categories, databases for the greenhouse-gas inventory, coordinating preparation of a balanced, harmonised National Inventory Report (NIR) and overarching topics relative to inventory preparation, such as quality assurance and control, uncertainties and data secrecy.

The event was aimed at persons who currently provide, or who may provide, contributions or data to the national greenhouse-gas inventory. This group includes Federal Environmental Agency specialists involved in inventory preparation, participating departments of ministries and of their subordinate authorities, representatives of the Länder, associations, working groups, research institutions and the Federal Statistical Office (DESTATIS).

The workshop provided both overarching, general information and information about specific source categories, with regard to the current status of greenhouse-gas-emissions reporting and relevant requirements. The event's topical emphases included:

1. The main requirements for greenhouse-gas reporting, on the basis of relevant international regulations and provisions;
2. The current status of implementation of such international requirements in Germany;
3. Specification of requirements in light of the SNE's experience with current reporting;
4. Specification of requirements on the basis of experience with, and results of, international reviews of greenhouse-gas inventories;
5. Specification of requirements in light of reporting of other countries;
6. Overarching requirements in implementation (for example, development of new data sources; ensuring provision of at least minimum data sets comprising data, uncertainties, methods and documentation; institutionalisation of data flows; data protection / secrecy, quality assurance /–control, etc..).

The workshop was divided into a general part, aimed at all participants, and sector-specific parts covering the areas of energy, industrial processes, agriculture, forestry and land-use changes. With respect to the area-specific sections, four working groups were formed; these groups worked concurrently, during the workshop, on selected issues relative to individual source categories within the areas. The workshop results, which will be used directly for inventory improvement, have been summarised in a workshop report.

17.2 German Quality System for Emissions Inventories

Since 2002, the national coordinating agency (SNE) has been working to develop and implement a QC/QA system (Quality System for Emissions Inventories - QSE). A research project is providing scientific support for the Federal Environmental Agency in implementing requirements from *Good Practice Guidance*. The QSE should serve to meet the requirements of the IPCC, and it should make allowance for the national situation in Germany and for the internal structures and procedures of Federal Environmental Agency (UBA), the reporting institution. The QSE's procedures should be flexible enough to be able to routinely incorporate future changes in requirements. The project will develop a procedural and organisational concept that addresses identified problem areas in emissions reporting and that transparently defines responsibilities for the procedure. At the same time, the process will link inventory preparation and QC/QA measures in a manner oriented to specific target groups.

17.2.1 Tasks of the Quality System of Emissions

The national coordinating agency (SNE) is charged with describing, introducing, updating and documenting QC/QA procedures. Such tasks apply both to procedures for quality assurance and control within the Federal Environmental Agency and to work with external data providers and organisations in the framework of the NaSE. The main elements of a QC/QA system that conforms to the minimum requirements of IPCC GPG (2000: Chapter 8.3) include:

- The QC/QA system must have an appointed coordinator. The QC/QA coordinator is responsible for maintaining the system and implementing the QC/QA plan, and he/she serves as a contact person for all of the Federal Environmental Agency's sections and for experts working in the framework of the NaSE;

- Implementation of a start-up organisation, with clearly defined responsibilities and competences,
- Preparation and maintenance of a QC/QA plan,
- Introduction and description of the necessary overarching and source-category-specific QC measures (Tier 1 + Tier 2),
- Introduction and description of the necessary internal and external quality assurance measures reviews, audits),
- Definition of documentation, recording and reporting obligations, and introduction of a procedure for document management,
- Procedures for monitoring, assessing and modifying the QC/QA system within the meaning of continual improvement,
- System documentation, in a suitable form (manual, guide).

The aforementioned QC/QA-system elements represent a concept for an ideal, IPCC-conformal emissions-reporting process (cf. Figure 72).

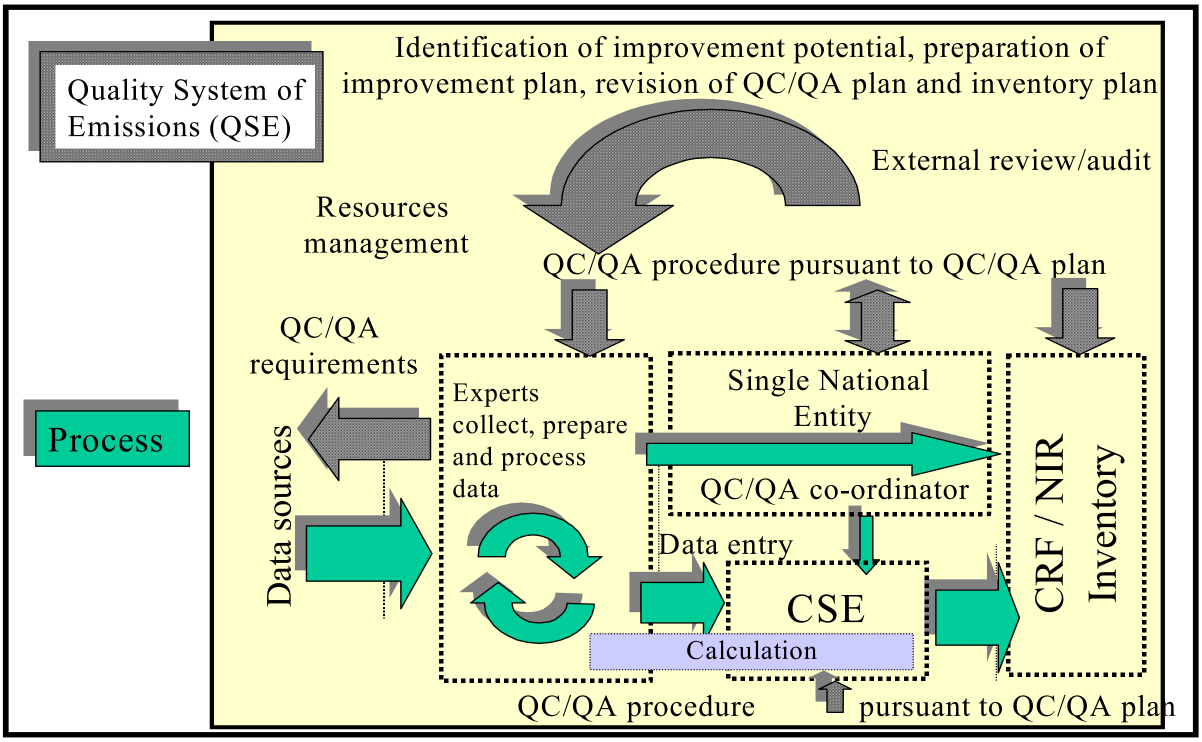


Figure 72: Ideal concept for the emissions-reporting process[98]

The QSE's scope of application comprises the entire emissions-reporting process:

- Data collection, including selection of methods and data sources
- Data preparation and emissions calculation
- Reporting

The term "data" includes figure and number data (activity data, emission factors and uncertainties, as well as material and calculation rules that can be used to obtain such data) and texts and documents, such as those that enter into the national inventory report.

[98] B/W arrows: flow of data/text; green arrows : QC/QA elements

The QSE is binding for all NaSE participants. Within the Federal Environmental Agency, the QSE has been made binding via the agency's internal directive (UBA-Hausanordnung) 11/2005. Plans call for the draft of the Act on climate-protection statistics (Klimaschutzstatistikgesetz) to include provisions relative to the binding nature of the QSE for other NaSE participants.

17.2.2 Structure of the Quality System of Emissions

17.2.2.1 Initial organisation

Within the QSE framework, a concept for initial, start-up organisation was developed that defines binding responsibilities and 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 140).

Table 140: Rollen und Verantwortlichkeiten im QSE

Role	Task	Responsible
QC/QA co-ordinator (QCC)	Overarching QC and QA throughout the entire reporting process Maintenance and further development of the QSE Management and updating of the QC/QA plan and QSE manual Description of quality targets Management and updating of the improvement plan, and management of relevant adoption in the inventory plan	An appointed staff member of the national co-ordinating agency (SNE)
NaSE co-ordinator	Ensuring on-time, requirements-conformal reporting Initiating implementation of overarching measures from the inventory plan Selection of institutions and collection of relevant informational materials, legal agreements Ensuring that all inventory information is archived, carrying out central archiving of inventory information Preparation of execution and post-processing of inventory reviews	An appointed staff member of the national co-ordinating agency (SNE)
Specialised contact person (source-category-specific) in the SNE	Facilitation of specialised and technical support (QC/QA, inventory work and reporting)	An appointed staff member of the national co-ordinating agency (SNE)
Contact persons in Federal Environmental Agency departments	Multipliers for departments and sections with regard to the national co-ordinating agency (SNE) information's and requirements relative to emissions reporting	An appointed member of each relevant department
QC/QA section representative	QC for data and report sections delivered to the national co-ordinating agency (SNE) Approval of report sections Ensuring that necessary inventory work, QC measures and documentation are carried out at the operational level Definition of specialised responsibilities for emissions reporting within the section in question	Heads of all affected sections
Specialised representative at the operational level	Data collection, entry and calculation, in keeping with the prescribed methods Definition of source-category-specific quality and review criteria Execution of QC measures Decentralised archiving of source-category-specific inventory information	All employees appointed by the relevant section head
CSE Administrator (CSE Admin)	Overarching QC and QA throughout the entire inventory process Approval of review criteria for the CSE Ensuring the integrity of databases Emissions reporting and data aggregation into report formats	An appointed staff member of the national co-ordinating agency (SNE)
Report co-ordinator (NIRC)	Contact person for section, for work related to the NIR Coordines support (collects work from section staff and distributes it within the national co-ordinating agency (SNE))	An appointed staff member of the national co-ordinating agency (SNE)

17.2.2.2 Initial organisation

Procedures for QC/QA measures in the CSE are oriented to the emissions-reporting process described in Chapter 1.3. At the same time, quality must be 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 process.

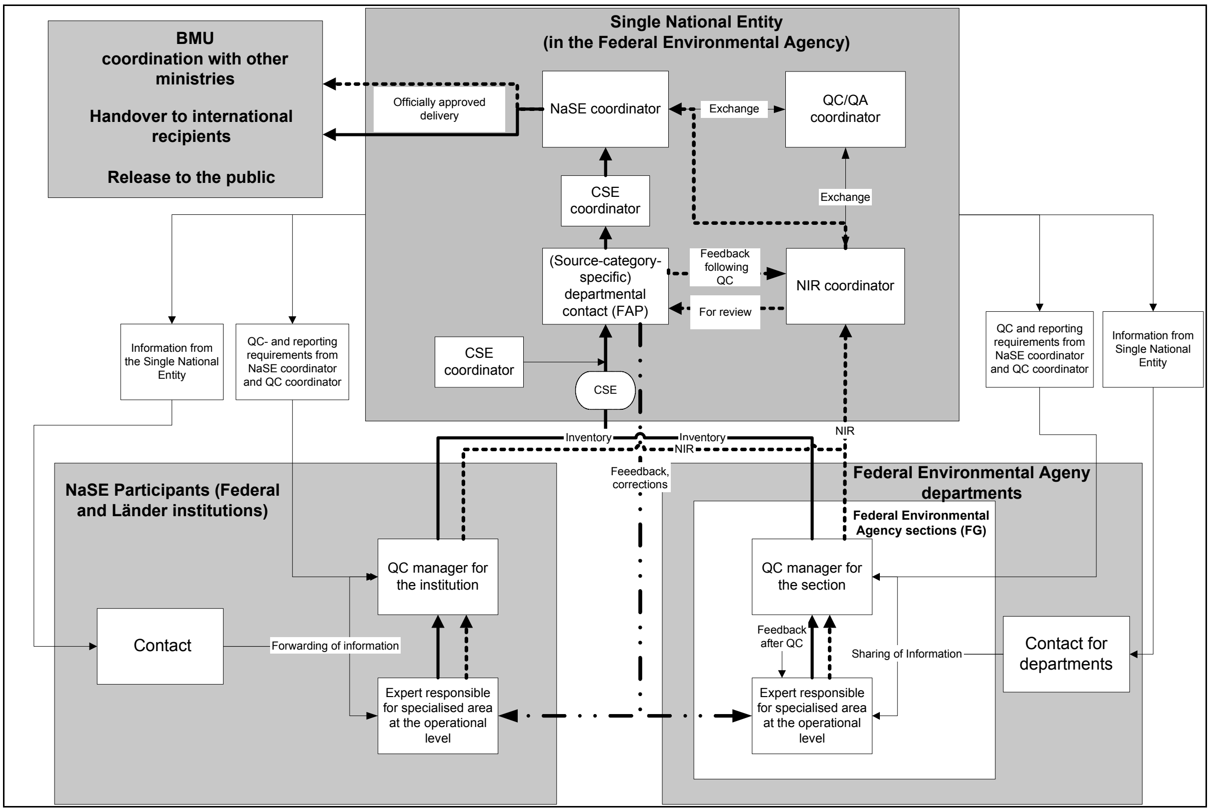


Figure 73: Roles and responsibilities in the QSE

The required QC checks were carried out for Tier 1 in 2005, for the first time. They were sent to the involved experts, in the form of QC checklists containing data requests, and then were completed throughout the course of support work. QC checks are actually defined not as checks but as quality targets; in each case, either compliance with the targets must be confirmed or non-compliance must be justified.

17.2.2.3 Documentation system

The QSE will be used to introduce the necessary QC/QA measures, pursuant to the IPCC, for the entire process of emissions reporting. Execution, description and documentation of QC/QA measures take place largely in conjunction with the relevant inventory contributions. To this end, a documentation system was developed that represents all such measures and related actions in an integrated manner tailoured to the specific parties and tasks concerned. The documentation system was introduced at the Federal Environmental Agency in 2004. Figure 74 presents the interrelationships between the various elements of the system.

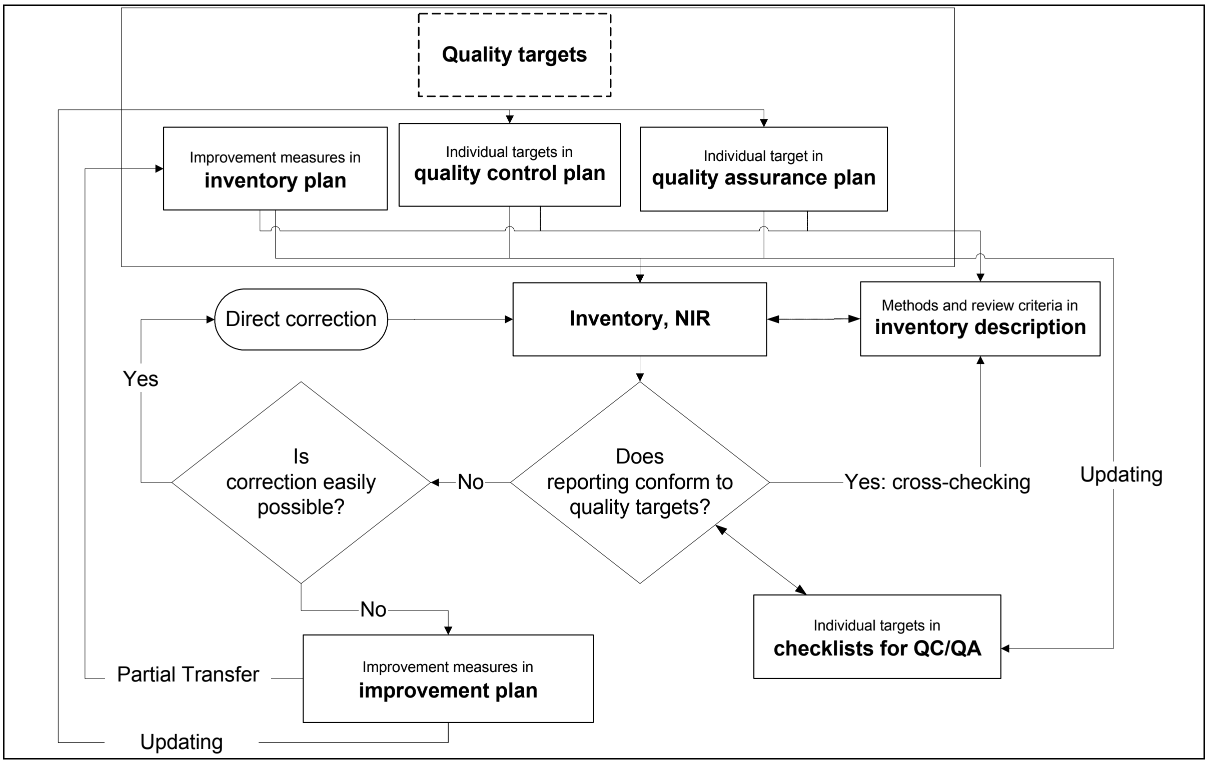


Figure 74: Control and documentation in the framework of the NaSE and the QSE

A general description of the **Quality targets** is provided in the QSE handbook; the description is derived from the *IPCC Good Practice Guidance*. In addition, operational individual targets, relative to quality control and quality assurance, for the various source categories, have to be derived from comparison of the requirements from the *IPCC Good Practice Guidance*, the results of independent inventory review and assessment of inventory realities.

To permit transparent, effective control of execution and monitoring of measures for achieving these targets, the measures are set forth in a **Quality control plan (QC plan)** with respect to specific roles – and, if necessary – specific source categories. The plan may be likened to a set of specifications for quality control. The quality control plan is a table that is generated from a master document that is also used for preparation of **checklists for quality control and quality assurance**.

The **quality assurance plan (QA plan)** sets forth, with respect to specific roles, the necessary individual targets for quality assurance. Quality assurance targets 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 plan may also be likened to a set of specifications. The **improvement plan** is a collection of all potential improvements, and criticisms, that result from independent inventory review and are identified in the framework of the relevant last completed emissions-reporting cycle. In the plan, such improvements and criticisms are correlated with feasible 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 coordination 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 source categories. The description covers all key aspects of inventory preparation. It includes descriptions of all work that pertains to specific source categories and that is relevant to preparation of source-category-specific inventories. The inventory description is really a collection of background information.

All QSE documentation with regard to the system's initial and regular organisation is managed within the framework of the QSE manual.

17.2.3 Quality targets

The purpose of the QSE is to introduce, maintain and improve procedures for continuously improving the quality of all emissions reporting (i.e. of the National Inventory Report and of relevant inventories), within the meaning of the *IPCC Good Practice Guidance*. This aim is described in terms of five general quality aims[99]: (cf. Figure 75).

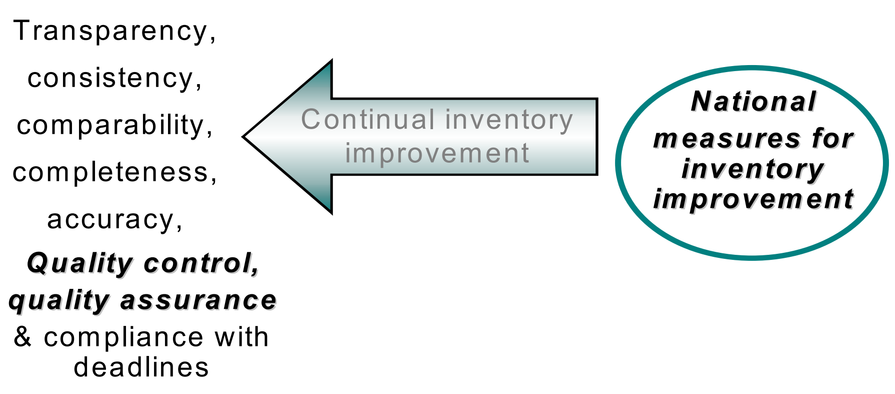


Figure 75: General quality targets of the QSE

Transparency means that the assumptions and methods used in preparation of emissions inventories must be clearly explained so that users can understand and assess the reported information. Transparency is of fundamental importance with regard to the success of an IPCC-conformal emissions-reporting process.

Consistency means that all elements of an emissions inventory are consistent with inventory elements from other years. An emissions inventory is consistent if the same methods are used for the base year and all subsequent years, and if consistent data records are used to calculate emissions and sinks. Under certain conditions, an emissions inventory may be considered consistent even if different emissions-calculation methods have been used, as

[99] For relevant explanations / definitions, see also Annex 3 (Glossary) of the *IPCC Good Practice Guidance*

long as relevant transparent recalculations have been carried out in conformance with the requirements of IPCC *Good Practice Guidance*. A consistent overall inventory results through avoidance of double counts in the inventory and through establishment, for all source categories, of congruency between the ways activity data and emission factors are delimited.

Comparability means that determined emissions and sinks may be compared across different source categories, and it means that the entire inventories of different states lend themselves to comparison. Comparability is achieved through standardised use of methods – such as that prescribed by *Good Practice Guidance*, for example. Furthermore, sub-elements must be allocated to the appropriate source categories in a standardised way.

Completeness means that the relevant inventory is complete with regard to the relevant gases and pollutants, as well as the relevant source categories and sinks. This also includes spatial/geographical completeness. And completeness also includes suitable documentation.

Accuracy refers to relative measurement of the precision of emissions and sink data. Identified emissions and sinks should be neither systematically overestimated nor systematically underestimated. Uncertainties should be reduced as far as possible. To this end, they must first be quantified.

The special quality targets pursuant to Tier 1 have been introduced by the Single National Entity within the framework of QC checklists. Source-category-specific / sectoral quality targets are to be subsequently defined, in keeping with the above principles, by the responsible experts, in co-operation with the QSE co-ordinator. Targets should be derived, inter alia, from completed QC/QA measures (internal/external reviews, audits, if applicable) and documented within the inventory plan.

17.3 The database system for emissions – Central System of Emissions

Since 1998, the UBA has developed a central national database – the *Central System of Emissions (CSE)* – as a technical tool for inventory preparation. The CSE implements the diverse requirements pertaining to emissions calculation and reporting, and it automates essential work stages. The CSE facilitates inventory planning reporting (e.g. emissions calculation, recalculation and error analysis) as well as inventory management (e.g. archiving, annual evaluation of data) and data-level quality management (cf. UBA 2003a, Decor project manual). The CSE should make it possible to fulfill the key requirements of transparency, consistency, completeness, comparability and accuracy on the data level.

In order to ensure fulfillment of these key requirements, careful attention is given to documentation within the CSE. In the CSE, records are kept of persons responsible for processing, of data sources and calculation procedures, of uncertainties relative to time series, of the date of each last change and of the persons who use such changes. The system has a history-management function that archives deleted entries. This facilitates the tracking and reconstruction of data, thereby also enabling an independent review by third parties. Supporting mechanisms are provided or developed at data level for the performance of quality assurance (e.g. system for detecting uncertainties, plausibility checks). Above all, transparency is accommodated by ensuring that data is recorded in the same structure in which it is provided, and that all processing and transformations into reporting format occur only in the CSE, in the interest of clarity. In this way, the CSE is capable of administering detailed technology-specific activity data and emission factors that can be processed, via calculation rules (calculation methods), into aggregate, source-category-specific values for the reporting formats. Aggregation of individual CSE time series for the CRF report lines is described in Annex 3 and Chapter 14f – in each case, with regard to individual source categories. In addition to aggregation and model formation for calculations, the CSE also supports scenario and forecast calculation.

Data exchange within the framework of the national system – i.e. within the Federal Environmental Agency and with third parties – is also organised via the CSE. In addition to being input directly, aggregate figures may also be imported from existing databases via a standard interface (e.g. TREMOD, GAS-EM). The aim is for technical experts responsible for content to enter inventory data directly into the CSE wherever possible or, at least, for the CSE administrator to import such data via the import interface. This applies to in-house UBA employees as well as to external parties involved in the National System. In order to achieve this, fundamental preparations have been carried out since 2001:

- Provision of a *standardised import format for CSE* in 2002 has facilitated the direct import of data from other emissions-relevant databases.
- In September 2002, participating technical experts from the UBA were given direct access to the CSE via the UBA intranet. The relevant parties are identified via an annual survey; as a result, virtually all of the responsible experts at the Federal Environmental Agency now have such access. However, write-access rights for these experts are normally confined to the database content for which they are technically responsible.
- In November 2002 and 2003, training courses in the CSE were held for relevant UBA staff members.
- Course participants were provided with a description of the database in the form of the *CSE/Point Source User Manual* (UBA, 2002c).

The CSE's operational launch in 2002 fulfilled the principal technical requirements for compliance with the Kyoto requirements for inventories; the next stage now is to bring emissions-calculation and data-collection procedures completely into line with the CSE. In 2005, the CSE will be connected to the Internet. This will enable external experts also to enter data directly into the CSE and conduct searches in it.

Other future tasks for the Central System for Emissions include comprehensive application of the database for:

- Recording of qualitative and quantitative information about data uncertainties,
- Complying with reporting obligations under the Geneva Convention on Long-Range Transboundary Air Pollution and EU legislation (such as the NEC directive),
- Measures-based orientation of emissions calculation to facilitate better quantification of the effectiveness of emissions-reduction measures in future, and
- Preparation of forecasts and scenarios to facilitate future estimates on compliance with reduction obligations and to facilitate identification of additional measures needed for target attainment.

17.3.1 Documentation of calculations in CalQlator

To support transparent documentation of calculations, the Federal Environmental Agency has developed a calculation tool for the CSE; this tool went into operation at the end of 2003. CalQlator makes it possible to store complex calculation methods in a user-friendly form in the database. It supports derivation of equations for linking entered values within calculations; once a formula has been entered, all calculation steps can be traced, and single changes trigger consistent recalculation of entire time series. Via a function for definition of inequalities, CalQlator can also be used for quality assurance – for example, via definition of checking parameters for maximum deviations. In January 2004, a first group of UBA staff received an introductory training course on CalQlator.

17.3.2 Data transfer between the TREMOD and CSE databases

In 1999/2000, an interface was programmed for transfer of emissions data, for the source category *road transport*, from the TREMOD (Transport Emission Estimation Model) database into the CSE database; in 2003, this interface was adapted to an upgraded version of the CSE database.

The current CSE import format is shown in Table 141 below.

Table 141: Dimensions in the CSE, and pertinent TREMOD categories

CSE heading	Description	TREMOD categories
SE:Name	Structural element	Vehicle category, vehicle layer, road category
Ts:Name	Time-series name	Like SE:Name
Spatial reference:Name	Germany, old German Länder, new German Länder	Scenario, Land
Value type:Name	Activity rate (energy consumption), emissions	Energy, component
Gas:Name	For example, carbon dioxide, sulphur dioxide	Component
EmiGru:Name	Source category – e.g. municipal road transport	Road category
VwA:Name	Type of use: Propulsion, evaporation	Emissions category (warm-up, ignition, evaporation)
Material:Name	Material (input) – e.g. diesel fuel * Energy Balance	Energy, energy balance, correction factor for energy balance
Measure:Name	Measure: Conventional, reduction equipment	Emission standard (vehicle layer)
Equipment:Name	Equipment – e.g. passenger automobile	Vehicle category
EBZ:Name	Energy Balance source – e.g. Road transport, 95	-
Unit	Units TJ, kg/TJ, t	

The most important category in the CSE is the structure element (SE). For it to be possible to derive activity rates and emission factors from TREMOD, for structure elements, several TREMOD categories have to be combined. A structure element thus consists of

- Road categories (in CSE, as "Emigruppe")
- Vehicle categories (in CSE aggregated to some extent under the "equipment" ("Technik") category)
- Vehicle layer (in the CSE category "Measure", differentiates between "conventional" and "reduction equipment")
- Emissions categories ("warm-up" and "ignition" correspond to the CSE area "propulsion"; "park" and "tank ventilation" correspond to the CSE area "evaporation")
- Energy (CSE category "Material"); the "material types" biodiesel, petroleum and LP gas are currently not included in TREMOD.

Table 142: Allocation of CSE structure elements (first line) and TREMOD category (second line)

SE:Name (ID)	EmiGru	Type of vehicle	Measure	Area	Material
-	SK	FzKat	Vehicle layer	Emissions category	Energy
SV LNFO KOAB	AB	LNF	KO: without reg. cat. conv.	Engine	Petrol
SV LNFO KOAO	ao	LNF	KO: without reg. cat. conv.	Engine	Petrol
SV LNFO KOIO	io	LNF	KO: without reg. cat. conv.	Engine	Petrol
SV LNFO KOVD	io	LNF	KO: without reg. cat. conv.	Evaporation	Petrol
SV LNFO MTAB	AB	LNF	MT: with reg. cat. conv.	Engine	Petrol
SV LNFO MTAO	ao	LNF	MT: with reg. cat. conv.	Engine	Petrol
SV LNFO MTIO	io	LNF	MT: with reg. cat. conv.	Engine	Petrol
SV LNFO MTVD	io	LNF	MT: with reg. cat. conv.	Evaporation	Petrol
SV MOPED	io	KKR	KO: All	Engine	Petrol
SV MOPED VD	io	KKR	KO: All	Evaporation	Petrol
SV MRAD KOAB	AB	KR	KO: before EURO1	Engine	Petrol
SV MRAD KOAO	ao	KR	KO: before EURO1	Engine	Petrol
SV MRAD KOIO	io	KR	KO: before EURO1	Engine	Petrol
SV MRAD KOVD	io	KR	KO: before EURO1	Evaporation	Petrol
SV MRAD MTAB	AB	KR	MT: as of Euro 1	Engine	Petrol
SV MRAD MTAO	ao	KR	MT: as of Euro 1	Engine	Petrol
SV MRAD MTIO	io	KR	MT: as of Euro 1	Engine	Petrol
SV MRAD MTVD	io	KR	MT: as of Euro 1	Evaporation	Petrol
SV PKWO KOAB	AB	Automobile	KO: without reg. cat. conv.	Engine	Petrol
SV PKWO KOAO	ao	Automobile	KO: without reg. cat. conv.	Engine	Petrol
SV PKWO KOIO	io	Automobile	KO: without reg. cat. conv.	Engine	Petrol, LP gas
SV PKWO KOVD	io	Automobile	KO: without reg. cat. conv.	Evaporation	Petrol
SV PKWO MTAB	AB	Automobile	MT: with reg. cat. conv.	Engine	Petrol
SV PKWO MTAO	ao	Automobile	MT: with reg. cat. conv.	Engine	Petrol
SV PKWO MTIO	io	Automobile	MT: with reg. cat. conv.	Engine	Petrol
SV PKWO MTVD	io	Automobile	MT: with reg. cat. conv.	Evaporation	Petrol
SV BUS KOAB	AB	RBus, LBus	KO: before EURO1	Engine	Diesel, biodiesel
SV BUS KOAO	ao	RBus, LBus	KO: before EURO1	Engine	Diesel, biodiesel, petroleum
SV BUS KOIO	io	RBus, LBus	KO: before EURO1	Engine	Diesel, biodiesel
SV BUS MTAB	AB	RBus, LBus	MT: as of Euro 1	Engine	Diesel, biodiesel
SV BUS MTAO	ao	RBus, LBus	MT: as of Euro 1	Engine	Diesel, biodiesel, petroleum
SV BUS MTIO	io	RBus, LBus	MT: as of Euro 1	Engine	Diesel, biodiesel
SV LNFD KOAB	AB	LNF	KO: before EURO1	Engine	Diesel, biodiesel
SV LNFD KOAO	ao	LNF	KO: before EURO1	Engine	Diesel, biodiesel
SV LNFD KOIO	io	LNF	KO: before EURO1	Engine	Diesel, biodiesel
SV LNFD MTAB	AB	LNF	MT: as of Euro 1	Engine	Diesel, biodiesel
SV LNFD MTAO	ao	LNF	MT: as of Euro 1	Engine	Diesel, biodiesel
SV LNFD MTIO	io	LNF	MT: as of Euro 1	Engine	Diesel, biodiesel
SV PKWD KOAB	AB	Automobile	KO: before EURO1	Engine	Diesel, biodiesel
SV PKWD KOAO	ao	Automobile	KO: before EURO1	Engine	Diesel, biodiesel
SV PKWD KOIO	io	Automobile	KO: before EURO1	Engine	Diesel, biodiesel
SV PKWD MTAB	AB	Automobile	MT: as of Euro 1	Engine	Diesel, biodiesel
SV PKWD MTAO	ao	Automobile	MT: as of Euro 1	Engine	Diesel, biodiesel
SV PKWD MTIO	io	Automobile	MT: as of Euro 1	Engine	Diesel, biodiesel
SV SNF KOAB	AB	LKW, LZ, SZ	KO: before EURO1	Engine	Diesel, biodiesel
SV SNF KOAO	ao	LKW, LZ, SZ	KO: before EURO1	Engine	Diesel, biodiesel
SV SNF KOIO	io	LKW, LZ, SZ	KO: before EURO1	Engine	Diesel, biodiesel
SV SNF MTAB	AB	LKW, LZ, SZ	MT: as of Euro 1	Engine	Diesel, biodiesel
SV SNF MTAO	ao	LKW, LZ, SZ	MT: as of Euro 1	Engine	Diesel, biodiesel
SV SNF MTIO	io	LKW, LZ, SZ	MT: as of Euro 1	Engine	Diesel, biodiesel

Remarks: FzKat: Vehicle category, SK: Road category, Material: cursive components not included in TREMOD; LKW = Truck

17.3.3 Next steps

The interface that has been developed is tailoured to the structure and data of TREMOD version 3.0 of 31 October 2002. TREMOD is currently being redesigned and expanded under commission to the Federal Highway Research Institute (BaSt) (IFEU, 2003b). In addition, integration of the new structures and results of the manual "Emissions factors for road transports" (Emissionsfaktoren des Straßenverkehrs) (INFRAS, 2003) is planned. This work will also require the CSE interface to be adapted.

It currently seems that the manual's new vehicle-layer definitions will necessitate at least a simple updating of the CSE interface. This adaptation will not require a complicated procedure for updating TREMOD.

In future, the fuels biodiesel, petroleum, LP gas and natural gas should be integrated into the TREMOD model. As part of TREMOD enhancement under commission to BASt, by mid-2004 suitable structures will be added to TREMOD that can accept suitable basic data and deliver results to CSE.

The 1994 data was broken down, in a simple manner, into data for the old and new German Länder; this procedure is to be supplanted by differentiation of input data (stocks, mileage) in the TREMOD database, to permit production of plausible time series for emissions of western and eastern Germany.

These changes are to be carried out as concurrently as possible with the updating process based on the new manual, since the emission factors in the new manual will nearly all be changed (changes will include retroactive changes).

17.4 The Web-based German Emission Factor Database (GEREF)

In the GEREF, the Federal Environmental Agency will present all emission factors for Germany that are being used to fulfill reporting obligations to the Secretariat of the Framework Convention on Climate and to the European Union. This database comprises the emission factors for Germany's national reporting.

To enhance the transparency and clarity of German emissions data, the UBA publishes these emission factors in the Internet, and it permits external experts (organisations, industry, research institutions) to submit (to the UBA) and publicise new emission factors and metadata. This makes it possible for the UBA to house a national database for emission factors that includes both emission factors for national reports and other emission factors that are collected. This, in turn, facilitates identification and discussion of differences to other emission factors, such as the international emission factors of the Emission Factors Database (EFDB), which the IPCC manages, along with supplementary information. GEREF includes an interface for transmission of German emission factors to the EFDB. Export of selected emission factors to the international EFDB will be managed by the Federal Environmental Agency.

GEREF has been implemented by the firm of Seven2one GmbH, using MESAP, a standard application. GEREF has an Internet Web client (browser) that enables the public to read-access emission factors. Registered users can also enter new emission factors and their meta-information, including technical data and literature references. Such entry can be carried out either manually, via the Web client, or automatically, via an Internet upload function.

The GEREF Web application, based on an MESAP solution:

- Is a database for administrating and documenting emission factors in Germany
- Provides Internet access to emission factors
- Enables visitors to search for and research emission factors
- Enables users (registered users) to enter new emission factors
- Is compatible with Federal Environmental Agency's existing databases
- Can easily be expanded to include indirect greenhouse gases and other air pollutants
- Supports data export to EFDB

18 ANNEX 7: TABLES 6.1 AND 6.2 OF THE IPCC GOOD PRACTICE GUIDANCE

Not all of the uncertainties for German greenhouse-gas inventories have been determined. Efforts in this area have begun with determination of uncertainties pursuant to Tier 1; they are being carried out by data-supplying experts of Federal Environmental Agency departments and by external institutions. Systematic and complete experts' estimatess are being hampered by the following issues, however:

- The fact that most activity rates are taken from data sources that are outside the Federal Environmental Agency (DESTATIS, industry associations or other statistics) complicates determination of uncertainties. Experts' judgements must be carried out either by experts outside of UBA, or the data-supplying institutions' own uncertainty figures must be used.
- Furthermore, many activity rates are determined through a process in which UBA carries out a variety calculations, for purposes of adaptation, on an external database (Examples include BEU, TREMOD, etc..). The question arises as to how changes in uncertainties resulting from such calculations, some of which are quite complex, can be determined.
- Furthermore, in some cases no further use of current emission factors and activity rates is planned. It thus must be asked whether it is at all useful to determine uncertainties for such values, which are badly in need of revision, or whether modification of calculation procedures has advanced enough to produce EF and AR for which uncertainties can be estimated.

The results of Tier 1 uncertainties analysis are shown, in keeping with the specifications given in Table 6.1 of IPCC Good Practice Guidance, in Table 143. At present, in light of the current status of relevant work, it is not yet possible to prepare Table 6.2 of the IPCC Good Practice Guidance.

Table 143: Uncertainties calculation pursuant to Tier 1 (in keeping with Table 6.1 GPG)

A		B	C	D	E	F	G	H	I	J	K	L	M	N	O
IPCC Greenhouse Gas Source and Sink Categories	Fuel Type	Direct Greenhouse Gas	Base Year emissions. 1990 GWP	Current Year emissions. 2003 GWP	Uncertainty		Combined uncertainty	Combined uncertainty as part of total national emissions in 2002	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions		Uncertainty introduced into the trend in total national emissions	Quality Indicator	
					AD	EF					introduced by emission factor uncertainty	introduced by activity data uncertainty		EF	AD
			[Gg CO_2-Equivalent]		[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]		
1A1a Public electricity and Heat production	Gaseous Fuels	N_2O	153.7	97.5	7	50	**50.5**	0.004838	-0.000023	0.000078	-0.001135	0.000776	**0,001375**	R	R
1A1a Public electricity and Heat production	Gaseous Fuels	CO_2	18463.3	26118.3	7	3	**7.6**	0.195488	0.008853	0.021002	0.026560	0.207907	**0,209597**	R	R
1A1a Public electricity and Heat production	Gaseous Fuels	CH_4	3.5	7.8	7	50	**50.5**	0.000387	0.000004	0.000006	0.000198	0.000062	**0,000208**	R	R
1A1a Public electricity and Heat production	Liquid Fuels	N_2O	98.5	21.1	7	50	**50.5**	0.001048	-0.000048	0.000017	-0.002391	0.000168	**0,002397**	R	R
1A1a Public electricity and Heat production	Liquid Fuels	CO_2	8474.8	4697.2	7	3	**7.6**	0.035157	-0.001798	0.003777	-0.005395	0.037391	**0,037778**	R	R
1A1a Public electricity and Heat production	Liquid Fuels	CH_4	8.1	4.2	7	50	**50.5**	0.000210	-0.000002	0.000003	-0.000096	0.000034	**0,000102**	R	R
1A1a Public electricity and Heat production	Other Fuels	N_2O	61.3	31.4	**7**	50	**50.5**	0.001557	-0.000015	0.000025	-0.000754	0.000250	**0,000794**	D	R
1A1a Public electricity and Heat production	Other Fuels	CO_2	1251.0	506.1	**7**	3	**7.6**	0.003788	-0.000416	0.000407	-0.001248	0.004029	**0,004218**	**D**	R
1A1a Public electricity and Heat production	Other Fuels	CH_4	12.8	1.3	**7**	50	**50.5**	0.000063	-0.000007	0.000001	-0.000369	0.000010	**0,000369**	**D**	R
1A1a Public electricity and Heat production	Solid Fuels	N_2O	3337.6	3311.1	5	50	**50.2**	0.163520	0.000467	0.002663	0.023334	0.018827	**0,029982**	R	R
1A1a Public electricity and Heat production	Solid Fuels	CO_2	306429.7	291320.9	5	3	**5.8**	1.669451	0.032571	0.234252	0.097713	1.656414	**1,659293**	R	R
1A1a Public electricity and Heat production	Solid Fuels	CH_4	109.1	87.8	5	50	**50.2**	0.004334	-0.000001	0.000071	-0.000062	0.000499	**0,000503**	R	R

A		B	C	D	E	F	G	H	I	J	K	L	M	N	O
					Uncertainty						Uncertainty in trend in national emissions			Quality Indicator	
IPCC Greenhouse Gas Source and Sink Categories	**Fuel Type**	**Direct Greenhouse Gas**	**Base Year emissions. 1990 GWP**	**Current Year emissions. 2003 GWP**	**AD**	**EF**	**Combined uncertainty**	**Combined uncertainty as part of total national emissions in 2002**	**Type A sensitivity**	**Type B sensitivity**	**introduced by emission factor uncertainty**	**introduced by activity data uncertainty**	**Uncertainty introduced into the trend in total national emissions**	**EF**	**AD**
			[Gg CO_2-Equivalent]		**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**		
1A1a Public electricity and Heat production	Biomass	N_2O	0.1	1.1	2	50	**50.0**	0.000053	0.000001	0.000001	0.000039	0.000002	**0,000039**	R	R
1A1a Public electricity and Heat production	Biomass	CO_2		0.0	2	3	**3.6**	0.000000	0.000000	0.000000	0.000000	0.000000	**0,000000**	R	R
1A1a Public electricity and Heat production	Biomass	CH_4	0.0	0.0	2	125	**125.0**	0.000002	0.000000	0.000000	0.000002	0.000000	**0,000002**	R	R
1A1b. Petroleum Refining	Gaseous Fuels	N_2O	8.6	3.7	7	75	**75.3**	0.000271	-0.000003	0.000003	-0.000203	0.000029	**0,000205**	R	R
1A1b. Petroleum Refining	Gaseous Fuels	CO_2	1028.7	725.0	7	1	**7.1**	0.005038	-0.000094	0.000583	-0.000094	0.005771	**0,005772**	R	R
1A1b. Petroleum Refining	Gaseous Fuels	CH_4	0.4	0.3	7	75	**75.3**	0.000026	0.000000	0.000000	0.000003	0.000003	**0,000004**	R	R
1A1b. Petroleum Refining	Liquid Fuels	N_2O	167.4	57.7	5	75	**75.2**	0.004262	-0.000064	0.000046	-0.004783	0.000328	**0,004794**	R	R
1A1b. Petroleum Refining	Liquid Fuels	CO_2	16008.9	18160.4	5	3	**5.8**	0.104071	0.004070	0.014603	0.012210	0.103258	**0,103977**	R	R
1A1b. Petroleum Refining	Liquid Fuels	CH_4	9.9	7.6	5	75	**75.2**	0.000560	0.000000	0.000006	-0.000031	0.000043	**0,000053**	R	R
1A1b. Petroleum Refining	Solid Fuels	N_2O	24.1	4.9	8	75	**75.4**	0.000366	-0.000012	0.000004	-0.000892	0.000045	**0,000894**	R	R
1A1b. Petroleum Refining	Solid Fuels	CO_2	2381.3	487.9	8	1	**8.1**	0.003866	-0.001174	0.000392	-0.001174	0.004439	**0,004592**	R	R
1A1b. Petroleum Refining	Solid Fuels	CH_4	0.8	0.1	8	75	**75.4**	0.000010	0.000000	0.000000	-0.000031	0.000001	**0,000031**	R	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Biomass	N_2O	4.6	5.4	**75**	50	**90.1**	0.000478	0.000001	0.000004	0.000064	0.000460	**0,000465**	D	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Biomass	CH_4	0.5	1.0	**75**	50	**90.1**	0.000090	0.000000	0.000001	0.000024	0.000087	**0,000090**	**D**	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Gaseous Fuels	N_2O	22.5	7.0	7	50	**50.5**	0.000347	-0.000009	0.000006	-0.000458	0.000056	**0,000461**	R	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Gaseous Fuels	CO_2	2701.7	1486.6	7	5	**8.6**	0.012568	-0.000582	0.001195	-0.002910	0.011834	**0,012186**	R	R

A		B	C	D	E	F	G	H	I	J	K	L	M	N	O
					Uncertainty			Combined uncertainty			Uncertainty in trend in national emissions		Uncertainty introduced	Quality Indicator	
IPCC Greenhouse Gas Source and Sink Categories	Fuel Type	Direct Greenhouse Gas	Base Year emissions. 1990 GWP	Current Year emissions. 2003 GWP	AD	EF	Combined uncertainty	as part of total national emissions in 2002	Type A sensitivity	Type B sensitivity	introduced by emission factor uncertainty	introduced by activity data uncertainty	into the trend in total national emissions	EF	AD
			[Gg CO_2-Equivalent]		[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]		
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Gaseous Fuels	CH_4	2.2	1.2	7	50	**50.5**	0.000061	0.000000	0.000001	-0.000021	0.000010	**0,000023**	R	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Liquid Fuels	N_2O	4.9	1.2	5	50	**50.2**	0.000062	-0.000002	0.000001	-0.000111	0.000007	**0,000111**	R	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Liquid Fuels	CO_2	488.4	216.4	5	5	**7.1**	0.001504	-0.000147	0.000174	-0.000736	0.001230	**0,001434**	R	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Liquid Fuels	CH_4	0.4	0.2	5	50	**50.2**	0.000009	0.000000	0.000000	-0.000007	0.000001	**0,000007**	R	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Other Fuels	N_2O	3.3	0.2	**7**	50	**50.5**	0.000011	-0.000002	0.000000	-0.000100	0.000002	**0,000100**	D	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Other Fuels	CO_2	333.1	4.6	**7**	5	**8.6**	0.000039	-0.000216	0.000004	-0.001078	0.000036	**0,001078**	**D**	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Other Fuels	CH_4	2.4	0.0	**7**	50	**50.5**	0.000000	-0.000002	0.000000	-0.000079	0.000000	**0,000079**	**D**	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Solid Fuels	N_2O	607.4	248.2	5	50	**50.2**	0.012259	-0.000200	0.000200	-0.010000	0.001411	**0,010099**	R	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Solid Fuels	CO_2	56384.0	18858.2	5	5	**7.1**	0.131053	-0.021921	0.015164	-0.109607	0.107225	**0,153333**	R	R

A		B	C	D	E	F	G	H	I	J	K	L	M	N	O
					Uncertainty			Combined uncertainty			Uncertainty in trend in national emissions		Uncertainty introduced	Quality Indicator	
IPCC Greenhouse Gas Source and Sink Categories	Fuel Type	Direct Greenhouse Gas	Base Year emissions. 1990 GWP	Current Year emissions. 2003 GWP	AD	EF	Combined uncertainty	as part of total national emissions in 2002	Type A sensitivity	Type B sensitivity	introduced by emission factor uncertainty	introduced by activity data uncertainty	into the trend in total national emissions	EF	AD
			[Gg CO_2-Equivalent]		[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]		
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Solid Fuels	CH_4	19.0	6.5	5	50	**50.2**	0.000323	-0.000007	0.000005	-0.000362	0.000037	**0,000364**	R	R
1A2a-f. Manufacturing Industries and Construction total	Biomass	N_2O	20.3		2	**150**	**150.0**	0.000000	-0.000013	0.000000	-0.002008	0.000000	**0,002008**	R	D
1A2a-f. Manufacturing Industries and Construction total	Biomass	CH_4	7.8		2	**75**	**75.0**	0.000000	-0.000005	0.000000	-0.000386	0.000000	**0,000386**	R	**D**
1A2a-f. Manufacturing Industries and Construction total	Gaseous Fuels	N_2O	380.8	239.6	8	50	**50.6**	0.011925	-0.000058	0.000193	-0.002893	0.002180	**0,003623**	R	R
1A2a-f. Manufacturing Industries and Construction total	Gaseous Fuels	CO_2	45751.0	50214.1	8	5	**9.4**	0.465568	0.010274	0.040377	0.051370	0.456818	**0,459697**	R	R
1A2a-f. Manufacturing Industries and Construction total	Gaseous Fuels	CH_4	28.6	37.7	8	50	**50.6**	0.001877	0.000012	0.000030	0.000577	0.000343	**0,000671**	R	R
1A2a-f. Manufacturing Industries and Construction total	Liquid Fuels	N_2O	266.6	103.8	6	50	**50.4**	0.005139	-0.000092	0.000083	-0.004594	0.000708	**0,004648**	R	R
1A2a-f. Manufacturing Industries and Construction total	Liquid Fuels	CO_2	28391.5	19040.6	6	1.5	**6.2**	0.115733	-0.003367	0.015311	-0.005051	0.129915	**0,130013**	R	R
1A2a-f. Manufacturing Industries and Construction total	Liquid Fuels	CH_4	24.9	13.2	6	50	**50.4**	0.000652	-0.000006	0.000011	-0.000291	0.000090	**0,000304**	R	R

A		B	C	D	E	F	G	H	I	J	K	L	M	N	O
IPCC Greenhouse Gas Source and Sink Categories	**Fuel Type**	**Direct Greenhouse Gas**	**Base Year emissions. 1990 GWP**	**Current Year emissions. 2003 GWP**	**Uncertainty**		**Combined uncertainty**	**Combined uncertainty as part of total national emissions in 2002**	**Type A sensitivity**	**Type B sensitivity**	**Uncertainty in trend in national emissions**		**Uncertainty introduced into the trend in total national emissions**	**Quality Indicator**	
					AD	**EF**					**introduced by emission factor uncertainty**	**introduced by activity data uncertainty**		**EF**	**AD**
			[Gg CO_2-Equivalent]		**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**		
1A2a-f. Manufacturing Industries and Construction total	Other Fuels	N_2O	48.8	17.9	**20**	5	**20.6**	0.000362	-0.000018	0.000014	-0.000088	0.000407	**0,000416**	D	R
1A2a-f. Manufacturing Industries and Construction total	Other Fuels	CO_2	1922.7	384.6	**20**	**7**	**21.2**	0.008009	-0.000956	0.000309	-0.006690	0.008747	**0,011012**	**D**	D
1A2a-f. Manufacturing Industries and Construction total	Other Fuels	CH_4	25.4	0.7		50	**50.0**	0.000034	-0.000016	0.000001	-0.000808	0.000000	**0,000808**	R	R
1A2a-f. Manufacturing Industries and Construction total	Solid Fuels	N_2O	1017.4	465.6	12	50	**51.4**	0.023531	-0.000295	0.000374	-0.014745	0.006354	**0,016056**	R	R
1A2a-f. Manufacturing Industries and Construction total	Solid Fuels	CO_2	120249.8	59416.9	12	**7**	**13.9**	0.811244	-0.031305	0.047777	-0.219135	0.810809	**0,839900**	R	D
1A2a-f. Manufacturing Industries and Construction total	Solid Fuels	CH_4	173.8	66.1	12	50	**51.4**	0.003342	-0.000061	0.000053	-0.003059	0.000902	**0,003189**	R	R
1A3a. Transport Civil Aviation	Aviation Gasoline	N_2O	18.2	63.3	**75**	200	**213.6**	0.013292	0.000039	0.000051	0.007787	0.005400	**0,009476**	D	R
1A3a. Transport Civil Aviation	Aviation Gasoline	CO_2	2897.4	4287.7	**75**	5	**75.2**	0.316745	0.001542	0.003448	0.007708	0.365689	**0,365770**	**D**	R
1A3a. Transport Civil Aviation	Aviation Gasoline	CH_4	0.8	1.1	**75**	200	**213.6**	0.000240	0.000000	0.000001	0.000076	0.000097	**0,000123**	**D**	**D**
1A3b. Transport Road Transportation	Diesel Oil	N_2O	705.3	1040.8	**20**	**75**	**77.6**	0.079394	0.000373	0.000837	0.027965	0.023670	**0,036638**	**D**	**D**
1A3b. Transport Road Transportation	Diesel Oil	CO_2	54458.1	79943.3	**20**	**7**	**21.2**	1.664822	0.028442	0.064283	0.199095	1.818190	**1,829058**	**D**	**D**

A		B	C	D	E	F	G	H	I	J	K	L	M	N	O
					Uncertainty			Combined uncertainty			Uncertainty in trend in national emissions		Uncertainty introduced	Quality Indicator	
IPCC Greenhouse Gas Source and Sink Categories	Fuel Type	Direct Greenhouse Gas	Base Year emissions. 1990 GWP	Current Year emissions. 2003 GWP	AD	EF	Combined uncertainty	as part of total national emissions in 2002	Type A sensitivity	Type B sensitivity	introduced by emission factor uncertainty	introduced by activity data uncertainty	into the trend in total national emissions	EF	AD
			[Gg CO_2-Equivalent]		[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]		
1A3b. Transport Road Transportation	Diesel Oil	CH_4	40.5	28.8	20	40	44.7	0.001265	-0.000004	0.000023	-0.000141	0.000655	0,000670	D	D
1A3b. Transport Road Transportation	Gasoline	CO_2	95794.5	79848.0	20	7	21.2	1.662837	0.001182	0.064206	0.008272	1.816022	1,816041	D	D
1A3b. Transport Road Transportation	Gasoline	N_2O	2227.0	3028.5	20	75	77.6	0.231028	0.000970	0.002435	0.072751	0.068878	0,100184	D	D
1A3b. Transport Road Transportation	Gasoline	CH_4	1276.7	199.8	20	40	44.7	0.008781	-0.000679	0.000161	-0.027172	0.004544	0,027549	D	D
1A3b. Transport Road Transportation	Liquid Gas	N_2O	0.1	0.1	20	75	77.6	0.000004	0.000000	0.000000	0.000000	0.000001	0,000001	D	D
1A3b. Transport Road Transportation	Liquid Gas	CO_2	9.0	6.5	20	7	21.2	0.000135	-0.000001	0.000005	-0.000005	0.000148	0,000148	D	D
1A3b. Transport Road Transportation	Liquid Gas	CH_4	0.0	0.0	20	40	44.7	0.000000	0.000000	0.000000	0.000000	0.000000	0,000000	D	D
1A3b. Transport Road Transportation	Petroleum	N_2O		0.6	20	75	77.6	0.000047	0.000001	0.000001	0.000038	0.000014	0,000040	D	D
1A3b. Transport Road Transportation	Petroleum	CO_2		44.4	20	7	21.2	0.000925	0.000036	0.000036	0.000250	0.001010	0,001040	D	D
1A3b. Transport Road Transportation	Petroleum	CH_4		0.0	20	40	44.7	0.000001	0.000000	0.000000	0.000001	0.000001	0,000001	D	D
1A3b. Transport Road Transportation	Biomass	CH_4		0.6	20	40	44.7	0.000028	0.000001	0.000001	0.000021	0.000015	0,000025	D	D
1A3b. Transport Road Transportation	Biomass	N_2O		23.3	20	75	77.6	0.001778	0.000019	0.000019	0.001406	0.000530	0,001503	D	D
1A3c. Transport Railways	Liquid Fuels	N_2O	40.5	22.2	20	75	77.6	0.001693	-0.000009	0.000018	-0.000662	0.000505	0,000832	D	D
1A3c. Transport Railways	Liquid Fuels	CO_2	2825.5	1557.7	20	7	21.2	0.032439	-0.000606	0.001253	-0.004245	0.035428	0,035681	D	D
1A3c. Transport Railways	Liquid Fuels	CH_4	4.0	2.2	20	40	44.7	0.000097	-0.000001	0.000002	-0.000035	0.000050	0,000061	D	D

A		B	C	D	E	F	G	H	I	J	K	L	M	N	O
IPCC Greenhouse Gas Source and Sink Categories	Fuel Type	Direct Greenhouse Gas	Base Year emissions. 1990 GWP	Current Year emissions. 2003 GWP	Uncertainty AD	Uncertainty EF	Combined uncertainty	Combined uncertainty as part of total national emissions in 2002	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	Quality Indicator EF	Quality Indicator AD
			[Gg CO_2-Equivalent]		[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]		
1A3c. Transport Railways	Solid Fuels	N_2O	0.7	0.6	**20**	**75**	**77.6**	0.000045	0.000000	0.000000	0.000000	0.000013	**0,000013**	**D**	**D**
1A3c. Transport Railways	Solid Fuels	CO_2	53.7	53.8	**20**	**7**	**21.2**	0.001121	0.000008	0.000043	0.000056	0.001224	**0,001226**	**D**	**D**
1A3c. Transport Railways	Solid Fuels	CH_4	0.2	0.2	**20**	**40**	**44.7**	0.000007	0.000000	0.000000	0.000001	0.000004	**0,000004**	**D**	**D**
1A3d. Transport Navigation	Diesel Oil	N_2O	29.2	11.0	**20**	**75**	**77.6**	0.000836	-0.000010	0.000009	-0.000780	0.000249	**0,000819**	**D**	**D**
1A3d. Transport Navigation	Diesel Oil	CO_2	2049.8	769.3	**20**	**7**	**21.2**	0.016021	-0.000730	0.000619	-0.005110	0.017497	**0,018227**	**D**	**D**
1A3d. Transport Navigation	Diesel Oil	CH_4	1.7	0.7	**20**	**40**	**44.7**	0.000029	-0.000001	0.000001	-0.000025	0.000015	**0,000029**	**D**	**D**
1A3e. Transport Other Transportation	Gaseous Fuels	N_2O	5.3	5.5	**20**	50	**53.9**	0.000290	0.000001	0.000004	0.000046	0.000125	**0,000133**	D	R
1A3e. Transport Other Transportation	Gaseous Fuels	CO_2	637.3	811.2	**20**	7	**21.2**	0.016893	0.000233	0.000652	0.001631	0.018449	**0,018521**	**D**	D
1A3e. Transport Other Transportation	Gaseous Fuels	CH_4	0.1	0.6	**20**	**40**	**44.7**	0.000027	0.000000	0.000000	0.000018	0.000014	**0,000022**	**D**	D
1A3e. Transport Other Transportation	Liquid Fuels	N_2O	52.3	41.4	**20**	**75**	**77.6**	0.003159	-0.000001	0.000033	-0.000083	0.000942	**0,000945**	**D**	D
1A3e. Transport Other Transportation	Liquid Fuels	CO_2	3634.3	2887.5	**20**	7	**21.2**	0.060133	-0.000069	0.002322	-0.000484	0.065673	**0,065675**	**D**	D
1A3e. Transport Other Transportation	Liquid Fuels	CH_4	9.8	6.4	**20**	**40**	**44.7**	0.000281	-0.000001	0.000005	-0.000051	0.000146	**0,000154**	**D**	D
1A4a. Other Sectors Commercial/Institutional	Biomass	N_2O	3.9	6.5	**75**	50	**90.1**	0.000575	0.000003	0.000005	0.000131	0.000553	**0,000569**	**D**	R
1A4a. Other Sectors Commercial/Institutional	Biomass	CH_4	26.0	39.6	**75**	100	**125.0**	0.004859	0.000015	0.000032	0.001467	0.003373	**0,003679**	**D**	R
1A4a. Other Sectors Commercial/Institutional	Gaseous Fuels	N_2O	25.7	52.1	11	35	**36.7**	0.001878	0.000025	0.000042	0.000875	0.000652	**0,001091**	R	R
1A4a. Other Sectors Commercial/Institutional	Gaseous Fuels	CO_2	13633.4	27227.0	11	2.5	**11.3**	0.301850	0.012922	0.021893	0.032306	0.340581	**0,342110**	R	R

A		B	C	D	E	F	G	H	I	J	K	L	M	N	O
IPCC Greenhouse Gas Source and Sink Categories	Fuel Type	Direct Greenhouse Gas	Base Year emissions. 1990 GWP	Current Year emissions. 2003 GWP	Uncertainty AD	Uncertainty EF	Combined uncertainty	Combined uncertainty as part of total national emissions in 2002	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	Quality Indicator EF	Quality Indicator AD
			[Gg CO_2-Equivalent]		[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]		
1A4a. Other Sectors Commercial/Institutional	Gaseous Fuels	CH_4	0.7	1.2	11	100	**100.6**	0.000119	0.000001	0.000001	0.000053	0.000015	**0,000055**	R	R
1A4a. Other Sectors Commercial/Institutional	Liquid Fuels	N_2O	63.3	47.1	10	70	**70.7**	0.003276	-0.000004	0.000038	-0.000262	0.000536	**0,000596**	R	R
1A4a. Other Sectors Commercial/Institutional	Liquid Fuels	CO_2	27280.4	20262.7	10	5	**11.2**	0.222646	-0.001654	0.016293	-0.008271	0.230422	**0,230571**	R	R
1A4a. Other Sectors Commercial/Institutional	Liquid Fuels	CH_4	0.2	0.1	10	200	**200.2**	0.000027	0.000000	0.000000	-0.000003	0.000002	**0,000004**	R	R
1A4a. Other Sectors Commercial/Institutional	Solid Fuels	N_2O	48.9	8.3	9	100	**100.4**	0.000818	-0.000025	0.000007	-0.002548	0.000085	**0,002549**	R	R
1A4a. Other Sectors Commercial/Institutional	Solid Fuels	CO_2	20901.8	1204.6	9	10	**13.5**	0.015928	-0.012781	0.000969	-0.127805	0.012329	**0,128399**	R	R
1A4a. Other Sectors Commercial/Institutional	Solid Fuels	CH_4	1057.5	23.2	9	150	**150.3**	0.003423	-0.000677	0.000019	-0.101566	0.000237	**0,101567**	R	R
1A4b. Other Sectors Residential	Biomass	N_2O	43.1	90.9	**75**	50	**90.1**	0.008055	0.000045	0.000073	0.002239	0.007755	**0,008072**	D	R
1A4b. Other Sectors Residential	Biomass	CH_4	234.9	472.8	**75**	100	**125.0**	0.058080	0.000226	0.000380	0.022558	0.040322	**0,046203**	**D**	R
1A4b. Other Sectors Residential	Gaseous Fuels	N_2O	54.3	103.9	11	35	**36.7**	0.003746	0.000048	0.000084	0.001673	0.001299	**0,002118**	R	R
1A4b. Other Sectors Residential	Gaseous Fuels	CO_2	31691.8	60536.0	11	2.5	**11.3**	0.671128	0.027820	0.048677	0.069550	0.757240	**0,760427**	R	R
1A4b. Other Sectors Residential	Gaseous Fuels	CH_4	13.1	25.0	11	100	**100.6**	0.002469	0.000011	0.000020	0.001148	0.000312	**0,001189**	R	R
1A4b. Other Sectors Residential	Liquid Fuels	N_2O	144.2	150.8	9	50	**50.8**	0.007532	0.000026	0.000121	0.001322	0.001544	**0,002033**	R	R

A		B	C	D	E	F	G	H	I	J	K	L	M	N	O
IPCC Greenhouse Gas Source and Sink Categories	Fuel Type	Direct Greenhouse Gas	Base Year emissions. 1990 GWP	Current Year emissions. 2003 GWP	Uncertainty		Combined uncertainty	Combined uncertainty as part of total national emissions in 2002	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions		Uncertainty introduced into the trend in total national emissions	Quality Indicator	
					AD	EF					introduced by emission factor uncertainty	introduced by activity data uncertainty		EF	AD
			[Gg CO_2-Equivalent]		[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]		
1A4b. Other Sectors Residential	Liquid Fuels	CO_2	56162.5	58965.0	9	5	**10.3**	0.596637	0.010460	0.047414	0.052299	0.603482	**0,605744**	R	R
1A4b. Other Sectors Residential	Liquid Fuels	CH_4	1.4	3.7	9	100	**100.4**	0.000370	0.000002	0.000003	0.000207	0.000038	**0,000210**	R	R
1A4b. Other Sectors Residential	Solid Fuels	N_2O	557.7	48.6	9	100	**100.4**	0.004792	-0.000328	0.000039	-0.032784	0.000497	**0,032787**	R	R
1A4b. Other Sectors Residential	Solid Fuels	CO_2	41425.1	2941.5	9	20	**21.9**	0.063402	-0.024880	0.002365	-0.497603	0.030105	**0,498513**	R	R
1A4b. Other Sectors Residential	Solid Fuels	CH_4	950.2	76.9	9	150	**150.3**	0.011351	-0.000563	0.000062	-0.084503	0.000787	**0,084506**	R	R
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Biomass	N_2O		2.9	2	50	**50.0**	0.000144	0.000002	0.000002	0.000118	0.000007	**0,000118**	R	R
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Biomass	CH_4		17.3	2	100	**100.0**	0.001702	0.000014	0.000014	0.001392	0.000039	**0,001393**	R	R
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Gaseous Fuels	N_2O	0.9	1.6	11	35	**36.7**	0.000058	0.000001	0.000001	0.000025	0.000020	**0,000032**	R	R
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Gaseous Fuels	CO_2	479.2	847.9	11	2.5	**11.3**	0.009400	0.000366	0.000682	0.000916	0.010606	**0,010645**	R	R
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Gaseous Fuels	CH_4	0.0	0.0	11	100	**100.6**	0.000004	0.000000	0.000000	0.000001	0.000000	**0,000002**	R	R
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Liquid Fuels	N_2O	82.1	61.2	20	75	**77.6**	0.004672	-0.000005	0.000049	-0.000356	0.001393	**0,001438**	R	R
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Liquid Fuels	CO_2	8088.7	5730.8	20	2.5	**20.2**	0.113521	-0.000713	0.004608	-0.001783	0.130339	**0,130351**	R	R
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Liquid Fuels	CH_4	14.1	8.9	20	200	**201.0**	0.001749	-0.000002	0.000007	-0.000429	0.000201	**0,000474**	R	R

A		B	C	D	E	F	G	H	I	J	K	L	M	N	O
					Uncertainty			Combined uncertainty			Uncertainty in trend in national emissions		Uncertainty introduced	Quality Indicator	
IPCC Greenhouse Gas Source and Sink Categories	Fuel Type	Direct Greenhouse Gas	Base Year emissions. 1990 GWP	Current Year emissions. 2003 GWP	AD	EF	Combined uncertainty	as part of total national emissions in 2002	Type A sensitivity	Type B sensitivity	introduced by emission factor uncertainty	introduced by activity data uncertainty	into the trend in total national emissions	EF	AD
			[Gg CO_2-Equivalent]		[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]		
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Solid Fuels	N_2O	12.6	1.2	7	50	**50.5**	0.000058	-0.000007	0.000001	-0.000367	0.000009	**0,000367**	R	R
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Solid Fuels	CO_2	4750.9	76.3	7	10	**12.2**	0.000915	-0.003064	0.000061	-0.030642	0.000607	**0,030648**	R	R
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Solid Fuels	CH_4	260.6	0.3	7	100	**100.2**	0.000026	-0.000171	0.000000	-0.017121	0.000002	**0,017121**	R	R
1A5 Other Include Military fuel use under this category	Gaseous Fuels	N_2O	0.8	1.0	11	35	**36.7**	0.000038	0.000000	0.000001	0.000011	0.000013	**0,000017**	R	R
1A5 Other Include Military fuel use under this category	Gaseous Fuels	CO_2	509.5	653.1	11	1	**11.0**	0.007090	0.000190	0.000525	0.000190	0.008170	**0,008172**	R	R
1A5 Other Include Military fuel use under this category	Gaseous Fuels	CH_4	0.0	0.0	11	100	**100.6**	0.000000	0.000000	0.000000	0.000000	0.000000	**0,000000**	R	R
1A5 Other Include Military fuel use under this category	Liquid Fuels	N_2O	59.7	12.8	20	70	**72.8**	0.000917	-0.000029	0.000010	-0.002027	0.000292	**0,002048**	R	R
1A5 Other Include Military fuel use under this category	Liquid Fuels	CO_2	6659.1	1355.8	20	2	**20.1**	0.026782	-0.003291	0.001090	-0.006581	0.030835	**0,031530**	R	R
1A5 Other Include Military fuel use under this category	Liquid Fuels	CH_4	26.6	5.7	20	50	**53.9**	0.000302	-0.000013	0.000005	-0.000644	0.000130	**0,000657**	R	R
1A5 Other Include Military fuel use under this category	Solid Fuels	N_2O	15.1	0.6	7	50	**50.5**	0.000029	-0.000009	0.000000	-0.000473	0.000005	**0,000473**	R	R
1A5 Other Include Military fuel use under this category	Solid Fuels	CO_2	4657.3	43.7	7	3	**7.6**	0.000327	-0.003029	0.000035	-0.009087	0.000348	**0,009093**	R	R
1A5 Other Include Military fuel use under this category	Solid Fuels	CH_4	210.3	0.3	7	50	**50.5**	0.000015	-0.000138	0.000000	-0.006904	0.000002	**0,006904**	R	R
1B1a. Fugitive Emissions from Fuels Coal Mining and Handling	Solid Fuels	CH_4	25644.4	6871.3	3	40	**40.1**	0.270880	-0.011344	0.005525	-0.453760	0.023441	**0,454365**	R	R

A		B	C	D	E	F	G	H	I	J	K	L	M	N	O
IPCC Greenhouse Gas Source and Sink Categories	**Fuel Type**	**Direct Greenhouse Gas**	**Base Year emissions. 1990 GWP**	**Current Year emissions. 2003 GWP**	**Uncertainty**		**Combined uncertainty**	**Combined uncertainty as part of total national emissions in 2002**	**Type A sensitivity**	**Type B sensitivity**	**Uncertainty in trend in national emissions**		**Uncertainty introduced into the trend in total national emissions**	**Quality Indicator**	
					AD	**EF**					**introduced by emission factor uncertainty**	**introduced by activity data uncertainty**		**EF**	**AD**
			[Gg CO_2-Equivalent]		**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**		
1B1b. Fugitive Emissions from Fuels Solid Fuel Transformation	Solid Fuels	CH_4	127.2	19.4	3	10	**10.4**	0.000199	-0.000068	0.000016	-0.000681	0.000066	**0,000684**	R	R
1B1c. Fugitive Emissions from Fuels Other (Abandoned Mines)	Solid Fuels	CH_4			**7**	**150**	**150.2**	0.000000	0.000000	0.000000	0.000000	0.000000	**0,000000**	**D**	**D**
1B2a. Fugitive Emissions from Fuels Oil	Oil	CH_4	226.6	137.4	1	20	**20.0**	0.002705	-0.000039	0.000111	-0.000771	0.000156	**0,000787**	R	R
1B2b. Fugitive Emissions from Fuels Natural Gas	Natural Gas	CH_4	6383.1	7214.0	18	37.5	**41.6**	0.294911	0.001601	0.005801	0.060046	0.147664	**0,159405**	R	R
1B2d. Fugitive Emissions from Fuels Other	Oil and Gas	CH_4	398.4		18	37.5	**41.6**	0.000000	-0.000262	0.000000	-0.009828	0.000000	**0,009828**	R	R
2A1. Mineral Products Cement Production		CO_2	15145.8	13373.4	1	20	**20.0**	0.263195	0.000789	0.010754	0.015781	0.015208	**0,021916**	R	R
2A2. Mineral Products Lime Production		CO_2	5890.8	5382.6	1	30	**30.0**	0.158788	0.000453	0.004328	0.013577	0.006121	**0,014893**	R	R
2A4. Soda Ash		CO_2	720.3	546.8	15	2	**15.1**	0.008132	-0.000034	0.000440	-0.000068	0.009327	**0,009327**	R	R
2A7. Glass Production		CO_2	1213.2	1455.7	5	**20**	**20.6**	0.029494	0.000372	0.001171	0.007447	0.008277	**0,011134**	R	D
2B1. Chemical Industry	Ammonia production	CO_2	1747.4	1997.7	1	5	**5.1**	0.010011	0.000457	0.001606	0.002284	0.002272	**0,003221**	R	R
2B2 Chemical Industry	Nitric Acid Production	N_2O	4673.4	6588.7	20	**75**	**77.6**	0.502620	0.002223	0.005298	0.166745	0.149850	**0,224185**	R	D
2B3 Chemical Industry	Adipic Acid Production	N_2O	18804.6	3778.3	20	**7**	**21.2**	0.078683	-0.009332	0.003038	-0.065324	0.085931	**0,107942**	R	**D**
2B4 Chemical Industry	Carbide Production	CO_2	443.2	15.9	20	**7**	**21.2**	0.000330	-0.000279	0.000013	-0.001952	0.000361	**0,001985**	R	**D**
2B5 Chemical Industry	other	N_2O	5.8	5.8	20	**75**	**77.6**	0.000440	0.000001	0.000005	0.000063	0.000131	**0,000146**	R	**D**

A		B	C	D	E	F	G	H	I	J	K	L	M	N	O
IPCC Greenhouse Gas Source and Sink Categories	Fuel Type	Direct Greenhouse Gas	Base Year emissions. 1990 GWP	Current Year emissions. 2003 GWP	Uncertainty AD	Uncertainty EF	Combined uncertainty	Combined uncertainty as part of total national emissions in 2002	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	Quality Indicator EF	Quality Indicator AD
			[Gg CO_2-Equivalent]		[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]		
2B5 Chemical Industry	other	CH_4	331.4	405.0	20	**150**	**151.3**	0.060229	0.000108	0.000326	0.016143	0.009210	**0,018586**	R	**D**
2C1. Metal Production Iron and Steel Production	other	CH_4	3.9	2.0	1	10	**10.0**	0.000020	-0.000001	0.000002	-0.000009	0.000002	**0,000010**	R	R
2C3. Aluminium Production		CO_2	1011.6	903.6	**7**	15	**16.6**	0.014700	0.000061	0.000727	0.000916	0.007193	**0,007251**	D	R
2C3. Aluminium Production		PFC	2486.0	431.0	5	15	**15.8**	0.006698	-0.001289	0.000347	-0.019334	0.002451	**0,019489**	R	R
2C4. SF_6 Used in Aluminium and Magnesium Foundries		SF_6	167.3	1217.5	**75**	**75**	**106.1**	0.126910	0.000869	0.000979	0.065168	0.103835	**0,122591**	**D**	**D**
2E. Production of Halocarbons and SF_6	production of HCFC-22	HFC	3510.0	1211.8	**75**	**40**	**85.0**	0.101227	-0.001335	0.000974	-0.053393	0.103348	**0,116325**	**D**	**D**
2E. Production of Halocarbons and SF_6	Fugitive emissions	SF_6		239.0	**75**	**75**	**106.1**	0.024914	0.000192	0.000192	0.014414	0.020384	**0,024965**	**D**	**D**
2E. Production of Halocarbons and SF_6		PFC	70.0		**75**	**75**	**106.1**	0.000000	-0.000046	0.000000	-0.003454	0.000000	**0,003454**	**D**	**D**
2F. Industrial Processes	Consumption of Halocarbons and SF_6	HFC		7035.4	**75**	**75**	**106.1**	0.733378	0.005657	0.005657	0.424289	0.600036	**0,734891**	**D**	**D**
2F. Industrial Processes	Consumption of Halocarbons and SF_6	PFC	140.0	355.0	**75**	**75**	**106.1**	0.037006	0.000193	0.000285	0.014501	0.030277	**0,033571**	**D**	**D**
2F. Industrial Processes	Consumption of Halocarbons and SF_6	SF_6	3728.4	2740.6	**75**	**75**	**106.1**	0.285685	-0.000249	0.002204	-0.018688	0.233742	**0,234488**	**D**	**D**
3D.Total Solvent and Other Product Use		N_2O	1922.0	1922.0	**75**	**20**	**77.6**	0.146620	0.000281	0.001545	0.005620	0.163924	**0,164020**	**D**	**D**
4A.1. Enteric Fermentation	Dairy Cattle	CH_4	12581.5	9433.9	10	25	**26.9**	0.249646	-0.000691	0.007586	-0.017286	0.107280	**0,108664**	R	R
4A.1. Enteric Fermentation	Non-Dairy Cattle	CH_4	20011.6	14268.2	10	25	**26.9**	0.377572	-0.001692	0.011473	-0.042309	0.162254	**0,167679**	R	R

A		B	C	D	E	F	G	H	I	J	K	L	M	N	O
IPCC Greenhouse Gas Source and Sink Categories	**Fuel Type**	**Direct Greenhouse Gas**	**Base Year emissions. 1990 GWP**	**Current Year emissions. 2003 GWP**	**Uncertainty**		**Combined uncertainty**	**Combined uncertainty as part of total national emissions in 2002**	**Type A sensitivity**	**Type B sensitivity**	**Uncertainty in trend in national emissions**		**Uncertainty introduced into the trend in total national emissions**	**Quality Indicator**	
					AD	**EF**					**introduced by emission factor uncertainty**	**introduced by activity data uncertainty**		**EF**	**AD**
			[Gg CO_2-Equivalent]		**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**		
4A.3. Enteric Fermentation	Sheep	CH_4	544.2	443.2	10	25	**26.9**	0.011728	-0.000002	0.000356	-0.000042	0.005040	**0,005040**	R	R
4A.6. Enteric Fermentation	Horses	CH_4	185.6	191.4	10	**40**	**41.2**	0.007754	0.000032	0.000154	0.001271	0.002176	**0,002520**	R	D
4A.8. Enteric Fermentation	Swine	CH_4	970.8	836.5	**7**	**40**	**40.6**	0.033386	0.000034	0.000673	0.001359	0.006659	**0,006796**	**D**	**D**
4B1. Manure Management	Dairy Cattle	CH_4	8693.6	7840.3	**7**	**40**	**40.6**	0.312899	0.000585	0.006304	0.023391	0.062410	**0,066650**	**D**	**D**
4B1. Manure Management	Non-Dairy Cattle	CH_4	5915.2	3890.2	**7**	**40**	**40.6**	0.155256	-0.000763	0.003128	-0.030539	0.030967	**0,043492**	**D**	**D**
4B3. Manure Management	Sheep	CH_4	12.6	10.3	**7**	**40**	**40.6**	0.000410	0.000000	0.000008	-0.000002	0.000082	**0,000082**	**D**	**D**
4B6. Manure Management	Horses	CH_4	28.0	28.9	**7**	**40**	**40.6**	0.001154	0.000005	0.000023	0.000192	0.000230	**0,000300**	**D**	**D**
4B8. Manure Management	Swine	CH_4	12262.2	11139.2	**7**	**40**	**40.6**	0.444555	0.000890	0.008957	0.035586	0.088670	**0,095545**	**D**	**D**
4B9. Manure Management	Poultry	CH_4	186.5	199.9	**7**	**40**	**40.6**	0.007979	0.000038	0.000161	0.001522	0.001591	**0,002202**	**D**	**D**
4B13. Manure Management Other	Dairy Cows	N_2O	1626.3	767.9	**7**	**75**	**75.3**	0.056848	-0.000452	0.000617	-0.033933	0.006113	**0,034479**	**D**	**D**
4B13. Manure Management Other	Other Cattle	N_2O	1335.4	984.5	**7**	**75**	**75.3**	0.072884	-0.000087	0.000792	-0.006518	0.007837	**0,010193**	**D**	**D**
4B13. Manure Management Other	Sheep	N_2O	15.0	10.4	**7**	**75**	**75.3**	0.000771	-0.000002	0.000008	-0.000113	0.000083	**0,000140**	**D**	**D**
4B13. Manure Management Other	Horses	N_2O	250.1	257.9	**7**	**75**	**75.3**	0.019092	0.000043	0.000207	0.003212	0.002053	**0,003812**	**D**	**D**
4B13. Manure Management Other	Swine	N_2O	784.8	414.2	**7**	**75**	**75.3**	0.030661	-0.000183	0.000333	-0.013748	0.003297	**0,014138**	**D**	**D**
4B13. Manure Management Other	Poultry	N_2O	462.9	491.5	**7**	**75**	**75.3**	0.036388	0.000091	0.000395	0.006802	0.003913	**0,007847**	**D**	**D**
4D1. Agricultural Soils	Direct Soil Emissions	N_2O	27645.2	23686.3	**75**	**150**	**167.7**	3.903973	0.000858	0.019046	0.128734	2.020163	**2,024261**	**D**	**D**
4D2. Agricultural Soils	Animal Production	N_2O	2518.8	1910.2	**20**	**75**	**77.6**	0.145718	-0.000121	0.001536	-0.009088	0.043444	**0,044384**	**D**	**D**

A		B	C	D	E	F	G	H	I	J	K	L	M	N	O
					Uncertainty			Combined uncertainty			Uncertainty in trend in national emissions		Uncertainty introduced	Quality Indicator	
IPCC Greenhouse Gas Source and Sink Categories	Fuel Type	Direct Greenhouse Gas	Base Year emissions. 1990 GWP	Current Year emissions. 2003 GWP	AD	EF	Combined uncertainty	as part of total national emissions in 2002	Type A sensitivity	Type B sensitivity	introduced by emission factor uncertainty	introduced by activity data uncertainty	into the trend in total national emissions	EF	AD
			[Gg CO_2-Equivalent]		[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]		
4D3. Agricultural Soils	Indirect Emissions	N_2O	13711.6	11156.3	**75**	**150**	**167.7**	1.838784	-0.000050	0.008971	-0.007505	0.951504	**0,951533**	**D**	**D**
4D4. Agricultural Soils	Other	CH_4	-672.0	-633.5	**75**	**75**	**106.1**	-0.066035	-0.000067	-0.000509	-0.005044	-0.054029	**0,054264**	**D**	**D**
6A1 Managed Waste Disposal on Land	Solid Waste Disposal on Land	CH_4	31478.9	11655.0	25	38.5	**45.9**	0.525815	-0.011335	0.009372	-0.436410	0.331344	**0,547944**	R	R
6B1. Wastewater Handling	Domestic and Commercial Wastewater	CH_4	2226.2	112.0	100	**40**	**107.7**	0.011854	-0.001375	0.000090	-0.054982	0.012736	**0,056438**	R	D
6B1. Wastewater Handling	Domestic and Commercial Wastewater	N_2O	2213.4	2275.4	100	**40**	**107.7**	0.240851	0.000373	0.001830	0.014938	0.258753	**0,259184**	R	**D**
		Total CO_2 Equivalent	**1243620,4**	**1017507.1**			**Total [%]**	**5.581134**				**Total [%]**	**4.285808**		

In further determination of uncertainties pursuant to Tier 1, in keeping with Chapter 6 of GPG, plans call for treating the source categories energy, transport and agriculture separately.

The current assumptions regarding uncertainties for activity rates in the source category Energy (CRF 1) are being reviewed by experts of the Working Group on Energy Balances (AG Energiebilanzen). The uncertainties for emission factors for CO_2 are being evaluated by experts in the Federal Environmental Agency's section (FG) III 2.3.

Uncertainties for activity rates in the source category Transport (primarily CRF 1 A 3) are also being estimated by experts of the Working Group on Energy Balances. The uncertainties in the emission factors for CH_4 and N_2O are being estimated by experts in the Federal Environmental Agency's section I 3.1 and I 3.2.

Uncertainties in the source category Agriculture (CRF 4) are being estimated by experts in the Federal Ministry of Foord, Agriculture and Consumer Protection (BMELV) and in the Federal Agricultural Research Institute (FAL).

Uncertainties for other source categories are being determined successively within the framework of UBA departments' data deliveries for current emissions reporting. At the same time, guideline-supported experts' judgements are being continued especially in those source categories in which very little or no uncertainties information has been provided to date in the framework of contributions/support.