Switzerland's Greenhouse Gas Inventory 1990-2013

National Inventory Report

Including reporting elements under the Kyoto Protocol

Submission of 15 April 2015
under the United Nations Framework Convention on Climate Change
and under the Kyoto Protocol

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Office for the Environment FOEN

Publisher

Federal Office for the Environment FOEN, Climate Division, 3003 Bern, Switzerland
www.bafu.admin.ch/climate
www.climatereporting.ch

Inventory Process Manager

Paul Filliger	FOEN, Climate Division, Bern

National Inventory Compiler

Anouk-Aimée Bass	FOEN, Air Pollution Control and Chemicals Division, Bern

NIR Lead Authors

Daniel Bretscher	Agroscope, Zürich
Jürg Heldstab	INFRAS, Zürich
Martin Herren	INFRAS, Zürich
Beat Rihm	Meteotest, Bern
Cornelia Stettler	Carbotech Basel
Jürg Walder	CSD, Basel

KP-LULUCF

Nele Rogiers	FOEN, Forest Division, Bern

QA/QC Officer

Regine Röthlisberger	FOEN, Climate Division, Bern

National Registry Administrator

Matthias Kohler	FOEN, Climate Division, Bern

Bern, 15 April 2015

Switzerland's Greenhouse Gas Inventory 1990–2013

National Inventory Report 2015

Including reporting elements under the Kyoto Protocol

Submission of 15 April 2015
under the United Nations Framework Convention on Climate Change
and under the Kyoto Protocol

NIR Chapter / Sector	Responsible Persons
Executive Summary	**Author**: Jürg Heldstab (INFRAS)
1. Introduction	**Lead Author**: Jürg Heldstab (INFRAS) **Authors**: Martin Herren (INFRAS); Regine Röthlisberger (FOEN; National System and QA/QC), Adrian Schilt (FOEN; KCA analysis Approach 1/2)
2. Trends in GHG Emissions and Removals	**Lead Authors**: Jürg Heldstab (INFRAS), Martin Herren (INFRAS)
3. Energy	**Lead Authors**: Jürg Heldstab (INFRAS), Martin Herren (INFRAS) **Sector expert** for Civil Aviation: Theo Rindlisbacher (FOCA) **Technical contributor:** Anouk Bass (FOEN; EMIS data base operation, QA/QC checks), Beat Müller (FOEN; Reference Approach), Benedikt Notter (INFRAS)
4. Industrial Processes and Product Use	**Lead Authors**: Jürg Walder (CSD; IPPU without F-gases), Cornelia Stettler (Carbotech; F-gases) **Technical contributor**: Sabine Schenker (FOEN; EMIS data base operation, QA/QC checks)
5. Agriculture	**Lead Author:** Daniel Bretscher (Agroscope) **Technical contributor:** Simon Liechti (FOEN; EMIS data base operation, QA/QC checks)
6. LULUCF	**Project Leader:** Andreas Schellenberger (FOEN) **Lead Author**: Beat Rihm (Meteotest) **Authors**: Paolo Camin (FOEN), Armin Keller (Agroscope), Jens Leifeld (Agroscope), Nele Rogiers (FOEN) **Sector experts**: Daniel Bretscher (ART), Esther Thürig (WSL), Markus Didion (WSL) **Technical contributors**: Christoph Könitzer (Sigmaplan), Stefan Müller (Meteotest), Felix Weibel (SFSO)
7. Waste	**Lead Author:** Jürg Heldstab (INFRAS) **Technical contributors:** Rainer Kegel (FOEN ; EMIS data base operation, QA/QC checks), Adrian Schilt (FOEN)
8. Other (IPCC sector 7)	**Lead Author:** Martin Herren (INFRAS)
9. Indirect CO_2 and Nitrous Oxide Emissions	**Lead Author:** Martin Herren (INFRAS) **Technical contributor**: Sabine Schenker (FOEN; EMIS data base operation, QA/QC checks)
10. Recalculations	**Authors:** Daniel Bretscher (Agroscope), Jürg Heldstab (INFRAS), Martin Herren (INFRAS), Cornelia Stettler (Carbotech), Jürg Walder (CSD)

15 April 2015

11. KP-LULUCF	**Lead Author:** Nele Rogiers (FOEN) **Sector experts:** Esther Thürig (WSL), Richard Volz (Meteotest)
12. Accounting of Kyoto units	**Authors:** Paul Filliger (FOEN), Stefan Meier (FOEN) **Sector experts:** Christine Kieffer (FOEN)
13. Changes in National Registry	**Author:** Stefan Meier (FOEN)
14. Minimization of adverse impacts	**Author:** Paul Filliger (FOEN)
Annex 1	**Author:** Martin Herren (INFRAS) **Sector expert:** Adrian Schilt (FOEN)
Annex 2	**Author:** Jürg Heldstab (INFRAS)
Annex 3	**Authors:** Daniel Bretscher (Agroscope), Martin Herren (INFRAS), Cornelia Stettler (Carbotech) Anouk Bass (FOEN)
Annex 4	**Authors:** Martin Herren (INFRAS), Regine Röthlisberger (FOEN)
Annex 5	**Author:** Stefan Reimann (Empa)

Table of Contents

Glossary

AD	Activity data
AFOLU	Agriculture, Forestry and Other Land Use
AREA1	Swiss Land Use Statistics 1979/85 (ASCH1 data re-evaluated according to the AREA set of land-use and land-cover categories)
AREA2	Swiss Land Use Statistics 1992/97 (ASCH2 data re-evaluated according to the AREA set of land-use and land-cover categories)
AREA3	Swiss Land Use Statistics, third survey 2004/09
ART	Agroscope Reckenholz-Tänikon Research Station (formerly FAL) since 2014 Agroscope
ASCH1	Swiss Land Use Statistics, first survey 1979/85
ASCH2	Swiss Land Use Statistics, second survey 1992/97
BCEF, BEF	Biomass conversion and expansion factor, biomass expansion factor
Carbura	Swiss organisation for the compulsory stockpiling of oil products
Cemsuisse	Association of the Swiss Cement Industry
CC	Combination category
CFC	Chlorofluorocarbon (organic compound: refrigerant, propellant)
CH_4	Methane, 2006 IPCC GWP: 25 (UNFCCC 2014a, Annex III)
CHP	Combined heat and power
CO	Carbon monoxide
CO_2, CO_2 eq	Carbon dioxide, carbon dioxide equivalent
CORINAIR	CORe INventory of AIR emissions (under the European Topic Centre on Air Emissions and under the European Environment Agency)
CRF	Common reporting format
DBH	Diameter (of trees) at breast height
DDPS	Federal Department of Defence, Civil Protection and Sport
DETEC	Dept. of the Environment, Transport, Energy and Communications
EF	Emission factor
EMEP	European Monitoring and Evaluation Programme (under the Convention on Long-range Transboundary Air Pollution)
EMIS	Swiss national air pollution database
EMPA	Swiss Federal Laboratories for Material Testing and Research
EV	Erdöl-Vereinigung (Swiss Petroleum Association)

FAL	Swiss Federal Research Station for Agroecology and Agriculture (since 2006: ART; since 2014 Agroscope)
FiBL	Research Institute of Organic Agriculture
FMRL	Forest Management Reference Level
FOAG	Federal Office for Agriculture
FOCA	Federal Office of Civil Aviation
FOEN	Federal Office for the Environment (former name SAEFL until 2005)
FOITT	Federal Office of Information Technology, Systems and Telecommunication
Gg	Gigagram (109 g = 1’000 tons)
GHG	Greenhouse gas
GL	Guidelines
GVS	Swiss Foundry Association
GWP	Global Warming Potential
ha	hectare
HFC	Hydrofluorocarbons (e.g. HFC-32 difluoromethane)
HWP	Harvested Wood Products
IDM	FOEN Internal Document Management System
IDP	Inventory Development Plan
IPCC	Intergovernmental Panel on Climate Change
KCA	Key category analysis
kha	Kilo hectare
kt	Kilo ton
LPG	Liquefied Petroleum Gas (Propane/Butane)
LTO	Landing-Takeoff-Cycle (Aviation)
LULUCF	Land Use, Land-Use Change and Forestry
MSW	Municipal solid waste
NABO	Swiss Soil Monitoring Network
NCV	Net calorific value
NFI 1, NFI 2	First (1983-1985), Second (1993-1995), Third (2004-2006)
NFI 3, NFI 4	and Fourth (2009-2017) National Forest Inventory
NIR	National Inventory Report
NIS	National Inventory System
NMVOC	Non-methane volatile organic compounds
N_2O	Nitrous oxide; 2006 IPCC GWP: 298 (UNFCCC 2014a, Annex III)

NO_x	Nitrogen oxides
PFC	Perfluorinated carbon compounds (e.g. Tetrafluoromethane)
SAEFL	Swiss Agency for the Environment, Forests and Landscape
	(since 2006: Federal Office for the Environment FOEN)
SBV	Schweizerischer Bauernverband; Swiss Farmers Union
SF_6	Sulphur hexafluoride, 2006 IPCC GWP: 22800 (UNFCCC 2014a, Annex III)
SFCA	Swiss Federal Customs Administration
SFOE	Swiss Federal Office of Energy
SFSO	Swiss Federal Statistical Office
SO_2	Sulphur dioxide
SOC	Soil organic carbon
SVGW/SSIGE/ SGWA	Schweizerischer Verein des Gas- und Wasserfaches / Société Suisse de l'Industrie du Gaz et des Eaux / Swiss Gas and Water Industry Association
SWISSMEM	Swiss Mechanical and Electrical Engineering Industries (Schweizer Maschinen-, Elektro- und Metallindustrie)
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
URH	Schifffahrt Untersee und Rhein
VOC	Volatile organic compounds
VSG	Verband der Schweizerischen Gasindustrie
WSL	Swiss Federal Institute for Forest, Snow and Landscape Research
WWT	Wastewater treatment

Executive Summary

ES 1 Background Information on Greenhouse Gas Inventories, Climate Change and Supplementary Information Required Under Art. 7.1. KP

ES 1.1 Background Information on Climate Change

Recent data confirms a warming trend in Switzerland with an observed increase in mean annual temperature of 1.75°C between 1864 and 2012 (FOEN 2014d). Over the last 30 years Swiss temperature has increased with an annual average warming rate of 0.35°C/decade (CH2011 2011). The most visible change in the Alps resulting from global warming is the retreat of glaciers, which showed a volume loss of 12% since 1999 (FOEN 2014d).

The observed trends in precipitation are less distinct than in temperature. They generally show an increase in winter and spring, whereas for summer and autumn no significant trends are detectable. Regional scenarios predict an increase in mean winter precipitation and a decrease in summer, which will have a marked impact on the hydrological cycle. Further, higher intensity of storms and reduced snowfall and snow cover duration are expected, increasing the risk and frequency of floods, landslides and debris flows.

Concerning biodiversity, climate change is expected to affect species composition, distribution, their cycles, synchronicity, the overall genetic diversity and the provision of ecosystem services. It will enhance the vulnerability of forests and potentially impair their protective, productive and social functions.

For agriculture, a moderate warming of 2°C to 3°C might increase productivity; however, if temperature will rise beyond that level, the increase in heat waves and drought periods would prove problematic for the cultivation of land and for livestock husbandry.

Various sectors of the Swiss economy are likely to be adversely affected by progressing climate change: in particular, winter tourism will suffer from increased scarcity of snow, hydroelectric power stations are confronted with altered runoff and sediment transport regimes, and insurance companies may face increased losses due to winter storms and floods. Natural hazards and extreme weather events potentially pose a growing risk to infrastructure and human health. Heat waves and elevated tropospheric ozone levels are cause for serious concern. Finally, it remains to be seen to what extent vector borne diseases spread due to changing climatic conditions. Recently Switzerland has analysed these challenges in detail and developed an effective adaptation strategy in order to hedge against negative effects resulting from climate change in Switzerland (FOEN 2012b).

ES.1.2 Background Information on Greenhouse Gas Inventories

On 10 December 1993, Switzerland ratified the United Nations Framework Convention on Climate Change (UNFCCC). Since 1996, the submission of its national greenhouse gas inventory has been based on IPCC guidelines. From 1998 onwards, the inventories have been submitted in the Common Reporting Format (CRF). In 2004, Switzerland started submitting a yearly National Inventory Report (NIR) under the UNFCCC.

On 9 July 2003, Switzerland ratified the Kyoto Protocol under the UNFCCC. The Swiss National Inventory System (NIS) according to Article 5.1 of the Kyoto Protocol has been implemented and is fully operational.

The 2015 inventory submission under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol includes the NIR on hand, the greenhouse gas inventory 1990–2013 and the Kyoto Protocol LULUCF tables 2008–2013 in the common reporting format as well as the SEF tables and the standard independent assessment report (SIAR) from the National Registry.

The Federal Office for the Environment (FOEN) is in charge of compiling the emission data and bears overall responsibility for Switzerland’s national greenhouse gas inventory and the national registry. In addition to the FOEN, the Swiss Federal Office of Energy (SFOE), the Agroscope Research Station and the Federal Office of Civil Aviation (FOCA) participate directly in the compilation of the inventory. Several other administrative offices and research institutions are involved in inventory preparation.

In preparing the national greenhouse gas inventory, Switzerland took into account the findings of the individual reviews of the inventory by the expert review teams of the UN (UNFCCC 2014c). The issues raised in the “Saturday Paper” (UNFCCC 2014d) and how they were resolved are included in the present submission (see Chapter 15).

The structure of Switzerland’s NIR corresponds to the UNFCCC annotated outline (UNFCCC 2014a) and it contains three parts: **PART 1** reports the obligations under the UNFCCC, **PART 2** the additional obligations under the Kyoto Protocol and several **Annexes** with detailed information on selected issues of Part 1 and Part 2.

Chapter 1 of the NIR, the introduction, provides an overview of Switzerland’s National System including institutional arrangements for producing the inventory, the process and methodologies used for inventory preparation, and the QA/QC procedures.

- The data sources used to compile the national inventory and to estimate greenhouse gas emissions and removals are: the Swiss national air pollution database (EMIS), national energy statistics, data from industry associations, as well as further statistics and models for road transportation, off-road vehicles and machinery, agriculture, land use, land-use change and forestry (LULUCF) and waste. Emissions are calculated according to methodologies recommended by the IPCC (IPCC 2006) including the recommended nomenclature and methodologies concerning uncertainty and QA/QC activities. The data in the EMIS database are pre-processed in order to enable transfer to the CRF Reporter required for reporting under the UNFCCC and under the Kyoto Protocol.
- All inventory data are assembled and prepared for input into the CRF Reporter by the GHG Inventory Core Group, which is responsible for ensuring the conformity of the inventory with the Updated UNFCCC Reporting Guidelines on Annual Inventories (UNFCCC 2014a) and the Guidance for reporting information on activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol (UNFCCC 2014b). In the preparation of this report, the Inventory Group was supported by consultants. Their mandate included editing of the NIR, data quality controls and an analysis of the consistency between the emission modelling and the recommendations of the IPCC Good Practice Guidance. Furthermore, the consultants contributed to the key category analyses and carried out the uncertainty analyses. They were also involved

in inventory improvement, e.g. by performing tasks contained in the Inventory Development Plan.

- The inventory quality management system is designed to comply with the objectives of good practice guidance, i.e. to ensure and improve transparency, consistency, comparability, completeness, accuracy and confidence in national GHG emission and removal estimates. The QA/QC Officer is responsible for enforcement of the defined quality standards. The National Inventory System complies with the ISO 9001:2008 standard (Quality Management System) and is certified by the Swiss TS Technical Services AG (Swiss-TS 2013).
- A National Inventory System Supervisory Board was established by decision of the FOEN Directorate in summer 2006. The Board oversees activities related to the GHG Inventory and to the National Registry.
- Furthermore, Chapter 1 provides information on key categories and uncertainties.

Chapter 2 contains an analysis of trends in Switzerland's greenhouse gas emissions by sources and removals by sinks for all sectors.

Chapters 3 to 9 provide principal source and sink category estimates.

Chapter 10 justifies, explains and summarises the recalculations and planned improvements. They result in a small increase of emissions by 0.58% (without LULUCF) in the base year emissions (1990) compared with the latest submission in 2014 and an even smaller change in the latest year of recalculations for the year 2012 by 0.25%. The chapter also contains an overview of the planned improvements.

In **PART 2, Chapter 11** reports KP LULUCF data, **Chapter 12** presents information on accounting of Kyoto Units, **Chapter 13** lists changes in the National System, **Chapter 14** includes information on minimization of adverse impacts in accordance with Article 3, paragraph 14 **Chapter 15** provides other information including the "Saturday Paper" (UNFCCC 2014d) that resulted from the 2014 review, together with the party's responses.

ES.1.3 Background Information on Supplementary Information Required under Article 7.1. of the Kyoto Protocol (KP)

Chapter 11 of PART 2 as mentioned above provides information on KP-LULUCF.

Switzerland only accounts for the mandatory activity Forest Management under Article 3, paragraph 4 of the Kyoto Protocol (FOEN 2015e). In accordance with Annex I to Decision 2/CMP.7 (Annex I, Para 13), credits from Forest Management are capped in the second commitment period. Thus for Switzerland the cap amounts to 3.5% of the 1990 emissions (excluding LULUCF).

Switzerland will choose to account over the entire second commitment period for emissions and removals from activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol (FOEN 2015e). In addition to the mandatory submission of the inventory year 2013, data for the years 1999-2012 are available and shown in Switzerland's NIR.

ES.2 Summary of National Emission and Removal Related Trends, and Emission and Removals from KP-LULUCF Activities

ES.2.1 GHG Inventory 2013

In 2013, Switzerland emitted 52'561 kt (kilo tons) CO_2 equivalent, corresponding to 6.50 tonnes CO_2 equivalent per capita (CO_2: 5.34 tonnes per capita), to the atmosphere, excluding emissions from international bunkers (aviation and marine) and excluding emissions and removals from the sector Land use, land-use change and forestry (LULUCF). For the emissions that are relevant under the Kyoto Protocol see chapter ES.3.3.

Several Key Category Analyses (including and excluding LULUCF for level (1990, 2013) and trend) are carried out.

- Approach 1 analysis (including LULUCF): for 2013, among a total of 150 categories, 30 have been identified as level key categories with an aggregated level contribution of 95.2% to total national emissions. Of the 30 key categories, 15 are in sector 1 Energy, accounting for 70.9% of total CO_2 equivalent emissions in 2013.
- Approach 2 analysis (including LULUCF): for 2013, among a total of 150 categories, 21 out of 150 categories have been identified for both 1990 and 2013 as key categories with an aggregated level contribution of 90.2% and 90.3% respectively to total national emissions. Because of its large uncertainty 4C1 Grassland remaining grassland (CO_2) contributes 23.1% to the level assessment.
- An Approach 1 and Approach 2 analysis without LULUCF was conducted as well.

Table E- 1 shows Switzerland's annual GHG emissions by individual GHGs from 1990 (base year) to 2013. Despite clear trends in some GHG emissions (see below), there is no significant trend in the total emissions of the period 1990–2013. Year-to-year variations of total emissions are mainly caused by changing winter temperatures and their effect on CO_2 emissions from fuel combustion (source category 1A4). In 2013, total gross GHG emissions (excluding LULUCF) show a decrease of 1.4% compared to the level recorded for 1990 (see also Table E- 2).

Table E- 1 Summary of Switzerland's GHG emissions in CO_2 equivalent (kt), 1990–2013. HFCs increased by 6'133'179% compared to 1990 levels (0.025 kt CO_2 equivalent).

Greenhouse Gas Emissions	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
	CO_2 equivalent (kt)									
CO2 emissions including net CO2 from LULUCF and HWP	40'956	43'213	43'095	39'641	39'720	39'658	41'017	39'562	41'396	42'008
CO_2 emissions excluding net CO_2 from LULUCF and HWP	44'031	46'101	45'973	43'556	42'593	43'352	44'088	42'980	44'540	44'364
CH_4 emissions including CH_4 from LULUCF	6'205	6'200	6'084	5'958	5'903	5'885	5'811	5'694	5'585	5'474
CH_4 emissions excluding CH_4 from LULUCF	6'169	6'186	6'072	5'946	5'885	5'864	5'795	5'649	5'569	5'463
N_2O emissions including N_2O from LULUCF	2'941	2'930	2'897	2'830	2'800	2'786	2'780	2'689	2'678	2'640
N_2O emissions excluding N_2O from LULUCF	2'854	2'848	2'816	2'748	2'717	2'702	2'697	2'602	2'597	2'560
HFCs	0	2	16	33	82	246	297	361	456	530
PFCs	117	99	81	35	21	17	20	21	24	26
SF_6	137	139	141	121	107	93	90	124	153	140
NF_3	0	0	0	0	0	0	0	0	0	0
Total (including LULUCF and HWP)	**50'355**	**52'582**	**52'314**	**48'617**	**48'632**	**48'686**	**50'015**	**48'452**	**50'292**	**50'818**
Total (excluding LULUCF and HWP)	**53'308**	**55'374**	**55'098**	**52'438**	**51'405**	**52'276**	**52'988**	**51'737**	**53'338**	**53'082**

Greenhouse Gas Emissions	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
	CO2 equivalent (kt)									
CO2 emissions including net CO2 from LULUCF and HWP	42'974	45'943	44'137	42'930	42'052	43'276	43'668	41'124	43'163	41'688
CO_2 emissions excluding net CO_2 from LULUCF and HWP	43'503	44'979	43'366	44'574	45'137	45'731	45'343	43'341	44'658	43'525
CH_4 emissions including CH_4 from LULUCF	5'382	5'370	5'309	5'200	5'139	5'150	5'186	5'209	5'289	5'201
CH_4 emissions excluding CH_4 from LULUCF	5'371	5'358	5'288	5'177	5'128	5'138	5'173	5'193	5'277	5'189
N_2O emissions including N_2O from LULUCF	2'635	2'650	2'628	2'579	2'535	2'532	2'531	2'554	2'573	2'535
N_2O emissions excluding N_2O from LULUCF	2'555	2'571	2'547	2'498	2'457	2'449	2'449	2'474	2'497	2'461
HFCs	625	723	802	897	1'020	1'071	1'118	1'194	1'245	1'253
PFCs	50	28	33	62	65	44	52	49	58	63
SF_6	144	145	158	165	186	203	186	172	222	180
NF_3	0	0	0	0	0	0	0	0	0	5
Total (including LULUCF and HWP)	**51'810**	**54'859**	**53'066**	**51'833**	**50'998**	**52'276**	**52'740**	**50'302**	**52'550**	**50'925**
Total (excluding LULUCF and HWP)	**52'247**	**53'803**	**52'194**	**53'373**	**53'993**	**54'635**	**54'319**	**52'423**	**53'957**	**52'676**

Greenhouse Gas Emissions	**2010**	**2011**	**2012**	**2013**	Change baseyear to 2013 (%)
	CO2 equivalent (kt)				
CO2 emissions including net CO2 from LULUCF and HWP	42'961	38'210	40'427	42'054	2.7%
CO_2 emissions excluding net CO_2 from LULUCF and HWP	45'050	40'983	42'242	43'173	-1.9%
CH_4 emissions including CH_4 from LULUCF	5'207	5'167	5'163	5'159	-16.9%
CH_4 emissions excluding CH_4 from LULUCF	5'196	5'152	5'151	5'148	-16.6%
N_2O emissions including N_2O from LULUCF	2'583	2'533	2'527	2'487	-15.4%
N_2O emissions excluding N_2O from LULUCF	2'509	2'460	2'454	2'415	-15.4%
HFCs	1'335	1'415	1'495	1'520	see caption
PFCs	64.57	67.76	71.31	52.01	-55.4%
SF_6	147.97	159.53	208.91	252.46	84.3%
NF_3	8.48	6.24	0.36	0.10	-
Total (including LULUCF and HWP)	**52'307**	**47'559**	**49'892**	**51'525**	**2.3%**
Total (excluding LULUCF and HWP)	**54'311**	**50'244**	**51'623**	**52'561**	**-1.4%**

With regard to the distribution of emissions by individual greenhouse gases, CO_2 is the largest single contributor to emissions, accounting for 82.1% of total gross GHG emissions (excluding LULUCF) in 2013 (1990: 82.6%). The share of CH_4 decreased from 11.6% (1990) to 9.8% (2013). Over the same period, the share of N_2O decreased from 5.4% to 4.6%, while the share of F-gases increased from 0.5% to 3.5%. The total GHG emissions excluding LULUCF decreased by 1.4% and increased by 2.3% including LULUCF in the period 1990-2013.

Table E- 2 Switzerland's total gross GHG emissions (excluding LULUCF) and the contribution of individual gases in CO_2 equivalent (kt), selected years.

Greenhouse Gas Emissions	1990		1995		2000		2005	
(excluding LULUCF and HWP)	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%
CO_2	44'031	82.6%	43'352	82.9%	43'503	83.3%	45'731	83.7%
CH_4	6'169	11.6%	5'864	11.2%	5'371	10.3%	5'138	9.4%
N_2O	2'854	5.4%	2'702	5.2%	2'555	4.9%	2'449	4.5%
HFCs	0	0.0%	246	0.5%	625	1.2%	1'071	2.0%
PFCs	117	0.2%	17	0.0%	50	0.1%	44	0.1%
SF_6	137	0.3%	93	0.2%	144	0.3%	203	0.4%
NF_3	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total (excluding LULUCF and HWP)	**53'308**	**100%**	**52'276**	**100%**	**52'247**	**100%**	**54'635**	**100%**

Greenhouse Gas Emissions	2010		2011		2012		2013	
(excluding LULUCF and HWP)	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%
CO_2	45'050	82.9%	40'983	81.6%	42'242	81.8%	43'173	82.1%
CH_4	5'196	9.6%	5'152	10.3%	5'151	10.0%	5'148	9.8%
N_2O	2'509	4.6%	2'460	4.9%	2'454	4.8%	2'415	4.6%
HFCs	1'335	2.5%	1'415	2.8%	1'495	2.9%	1'520	2.9%
PFCs	65	0.1%	68	0.1%	71	0.1%	52	0.1%
SF_6	148	0.3%	160	0.3%	209	0.4%	252	0.5%
NF_3	8	0.0%	6	0.0%	0	0.0%	0	0.0%
Total (excluding LULUCF and HWP)	**54'311**	**100%**	**50'244**	**100%**	**51'623**	**100%**	**52'561**	**100%**

Figure E- 1 shows the shares of 2013 emissions contributed by individual greenhouse gases. As the shares of emissions contributed by the individual gases have remained relatively constant, the diagram is also representative of the other years in the period 1990–2013.

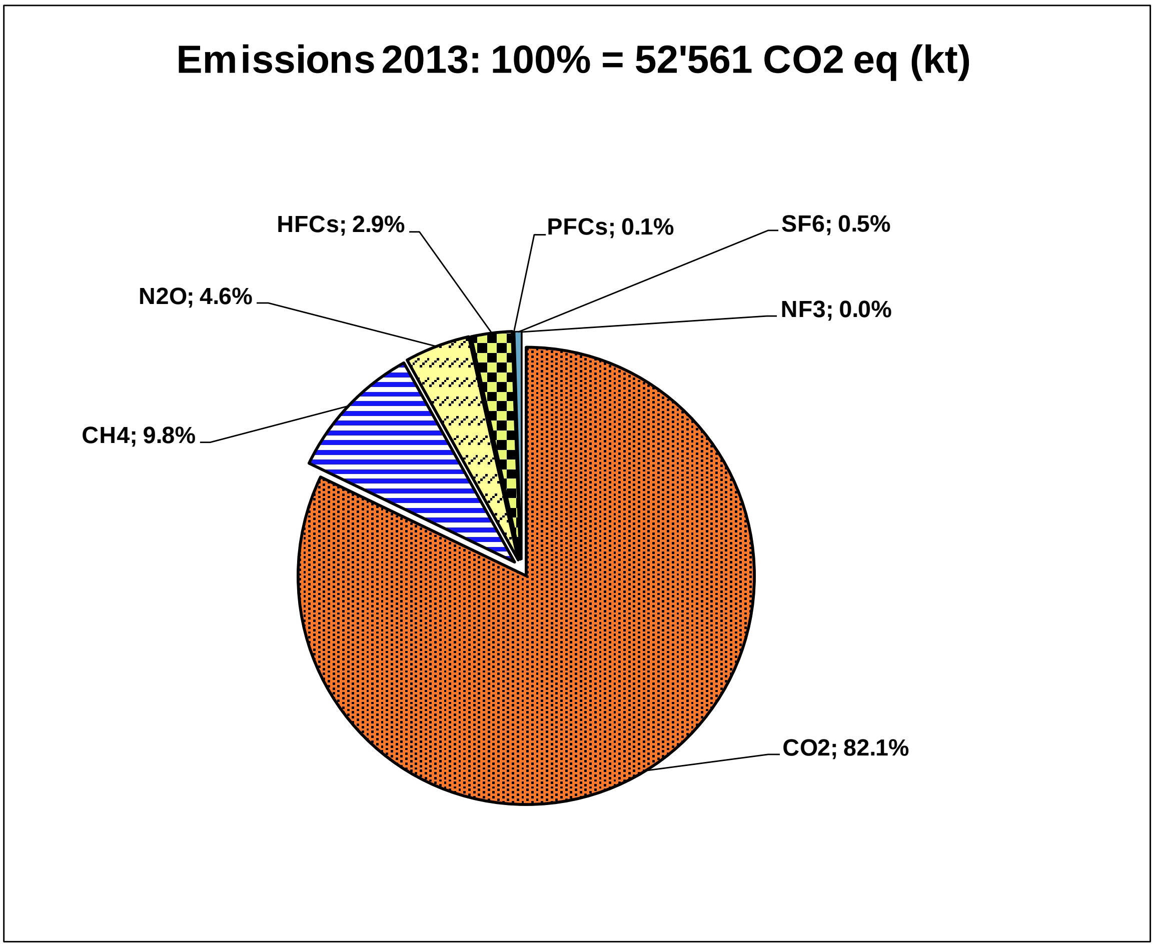


Figure E- 1 Contribution of individual gases to Switzerland's GHG emissions (excluding LULUCF) in 2013. 100% = 52'561 kt CO_2 eq. (Numbers may not add to total due to rounding.)

Table E- 3 Switzerland's relative uncertainties for national total GHG emission excluding and including the LULUCF sector – Approach 1: Level uncertainties 2013 and trend uncertainties 1990-2013.

Approach 1 Uncertainty Analysis		
Inventory	**Level uncertainty 2013**	**Trend uncertainty 1990-2013**
excl. LULUCF	3.69%	1.95%
incl. LULUCF	7.08%	2.99%

For the emission data of 2013 excluding LULUCF, an uncertainty analysis on Approach 1 level was carried out (see resulting in a **level uncertainty of 3.69% (2013) and a trend uncertainty of 1.95% (1990-2013)**. The analysis was also carried out including the LULUCF sector resulting in increases of the uncertainties to 7.08% (level uncertainty) and 2.99% (trend uncertainty). Approach 2 shows different uncertainties due to accounting for asymmetric probability distributions and correlations**: The level uncertainty is 3.38% (2013) and the trend uncertainty 2.50% (1990-2013)**. Including the LULUCF sector, the level uncertainty is 6.78% and the trend uncertainty 7.98%.

Chapter 10 explains and justifies recalculations that have been performed since the previous inventory submission to the UNFCCC secretariat in September 2014 after the centralized review 2014. The recalculations result in an increase of the total base year (1990) emissions of 0.58% in CO_2 equivalents compared to the previous inventory (without LULUCF). For the year 2012 emissions, the increase is 0.25% without emissions and removals from LULUCF. If the LULUCF sector is included there is an increase of 0.97% in 1990 and a decrease of 0.37% in 2012.

ES.2.2 KP-LULUCF Activities

Switzerland reports the mandatory LULUCF activities Afforestation and Deforestation (Reforestation is not occurring in Switzerland) under Article 3, paragraph 3 of the Kyoto Protocol, and Forest Management as a mandatory activity under Article 3, paragraph 4 of the Kyoto Protocol. The contribution of harvested wood products (HWP) from forests accounted for under Article 3, paragraph 4 of the Kyoto Protocol are also listed. The total contribution of these activities is shown in

Table E- 4.

Table E- 4 Emissions (positive sign) and removals (negative sign) of activities accounted for under Article 3, paragraph 3 and paragraph 4 (Forest Management and HWP) of the Kyoto Protocol, kt CO_2 eq., 1999-2013.

Greenhouse gas source and sink activities	1999	2000	2001	2002	2003	2005	2005	2006
	Net CO_2 equivalent emissions/removals (kt CO_2 eq)							
Article 3.3 activities	156.42	155.78	154.64	153.42	152.21	151.32	124.96	102.44
Article 3.4 FM	-3013.06	-74.89	450.67	484.87	-2187.34	-2569.04	-2407.81	-2200.73
Article 3.4 HWP	-485.54	-837.52	-582.32	-453.53	-448.75	-644.41	-771.69	-633.43

Greenhouse gas source and sink activities	2007	2008	2009	2010	2011	2012	2013	2014
	Net CO_2 equivalent emissions/removals (kt CO_2 eq)							
Article 3.3 activities	80.00	53.04	117.45	145.20	146.21	147.14	147.60	
Article 3.4 FM	-1636.91	-1447.67	-2003.56	-2701.27	-2600.01	-2660.79	-2290.79	
Article 3.4 HWP	-741.76	-524.55	-479.46	-509.57	-369.81	-299.55	-158.15	

ES.3. Overview of Source and Sink Category Estimates and Trends, including KP-LULUCF Activities

ES.3.1 GHG Inventory (Convention on Climate Change)

Table E- 5 and Figure E- 2 show the GHG emissions and removals by the main source and sink categories. The energy sector is by far the largest source of national emissions, accounting for 78.9% of the total GHG emissions (excluding LULUCF). There are decreasing trends in the source categories 3 Agriculture and 5 Waste, as well as an increasing trend in source category 2 Industrial processes. However, there is no significant trend in total emissions over the period 1990–2013 due to the dominating emissions of the energy sector with its year-to-year variability caused by changing winter temperatures and their effect on CO_2 emissions from fuel combustion.

Table E- 5 Switzerland's GHG emissions and removals by source and sink categories in CO_2 equivalent (kt), 1990–2013.

Source and Sink Categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	CO_2 equivalent (kt)									
1. Energy	41'707	44'177	44'207	42'026	40'890	41'803	42'717	41'749	43'298	43'093
1A1 Energy industries	2'558	2'851	2'946	2'617	2'661	2'698	2'917	2'912	3'273	3'298
1A2 Manufacturing industries and construction	6'260	6'562	6'138	5'967	5'896	6'069	5'872	5'798	5'995	5'857
1A3 Transport	14'613	15'105	15'428	14'359	14'545	14'229	14'290	14'847	15'058	15'667
1A4 Other sectors	17'666	19'021	19'052	18'439	17'159	18'200	19'042	17'603	18'408	17'746
1A5 Other	206	188	180	171	166	148	137	147	146	132
1B Fugitive emissions from fuels	405	449	463	472	464	459	458	441	419	394
2. Industrial processes	3'522	3'157	2'997	2'691	2'881	2'873	2'749	2'666	2'782	2'845
3. Agriculture	6'713	6'674	6'557	6'456	6'440	6'413	6'367	6'182	6'141	6'055
5. Waste	1'355	1'354	1'324	1'253	1'181	1'173	1'142	1'126	1'103	1'076
6. Other sources	12	12	13	13	13	13	13	14	14	14
Total (excluding LULUCF and HWP)	53'308	55'374	55'098	52'438	51'405	52'276	52'988	51'737	53'338	53'082
4. Land use, land-use change and forestry and harvested wood products	-2'953	-2'792	-2'784	-3'821	-2'773	-3'590	-2'973	-3'285	-3'046	-2'264
Total (including LULUCF and HWP)	50'355	52'582	52'314	48'617	48'632	48'686	50'015	48'452	50'292	50'818

Source and Sink Categories	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	CO_2 equivalent (kt)									
1. Energy	42'061	43'489	41'892	43'109	43'457	43'918	43'567	41'526	42'886	41'815
1A1 Energy industries	3'216	3'358	3'434	3'427	3'712	3'840	4'056	3'739	3'850	3'696
1A2 Manufacturing industries and construction	5'775	6'040	5'594	5'709	5'841	5'885	6'072	5'879	5'904	5'607
1A3 Transport	15'900	15'602	15'528	15'697	15'777	15'838	15'952	16'273	16'640	16'443
1A4 Other sectors	16'660	17'993	16'851	17'822	17'691	17'923	17'053	15'226	16'090	15'674
1A5 Other	136	134	140	125	114	123	127	120	115	116
1B Fugitive emissions from fuels	373	361	344	328	322	308	306	288	287	278
2. Industrial processes	3'098	3'198	3'235	3'327	3'621	3'775	3'757	3'823	3'904	3'796
3. Agriculture	6'029	6'089	6'054	5'976	5'954	5'993	6'022	6'076	6'180	6'091
5. Waste	1'046	1'013	999	947	948	935	960	984	974	959
6. Other sources	14	14	14	14	14	14	14	14	14	14
Total (excluding LULUCF and HWP)	52'247	53'803	52'194	53'373	53'993	54'635	54'319	52'423	53'957	52'676
4. Land use, land-use change and forestry and harvested wood products	-437	1'055	872	-1'540	-2'995	-2'359	-1'579	-2'121	-1'407	-1'751
Total (including LULUCF and HWP)	51'810	54'859	53'066	51'833	50'998	52'276	52'740	50'302	52'550	50'925

Source and Sink Categories	2010	2011	2012	2013	2013/1990
	CO_2 equivalent (kt)				%
1. Energy	43'192	39'145	40'525	41'452	-0.6%
1A1 Energy industries	3'873	3'620	3'653	3'678	43.8%
1A2 Manufacturing industries and construction	5'718	5'271	5'267	5'377	-14.1%
1A3 Transport	16'340	16'224	16'352	16'245	11.2%
1A4 Other sectors	16'856	13'645	14'886	15'768	-10.7%
1A5 Other	121	108	116	117	-43.2%
1B Fugitive emissions from fuels	283	276	251	267	-34.1%
2. Industrial processes	4'017	4'051	4'056	4'093	16.2%
3. Agriculture	6'108	6'052	6'015	5'949	-11.4%
5. Waste	981	983	1'013	1'053	-22.3%
6. Other sources	14	14	14	14	16.1%
Total (excluding LULUCF and HWP)	54'311	50'244	51'623	52'561	-1.4%
4. Land use, land-use change and forestry and harvested wood products	-2'005	-2'685	-1'731	-1'036	-64.9%
Total (including LULUCF and HWP)	52'307	47'559	49'892	51'525	2.3%

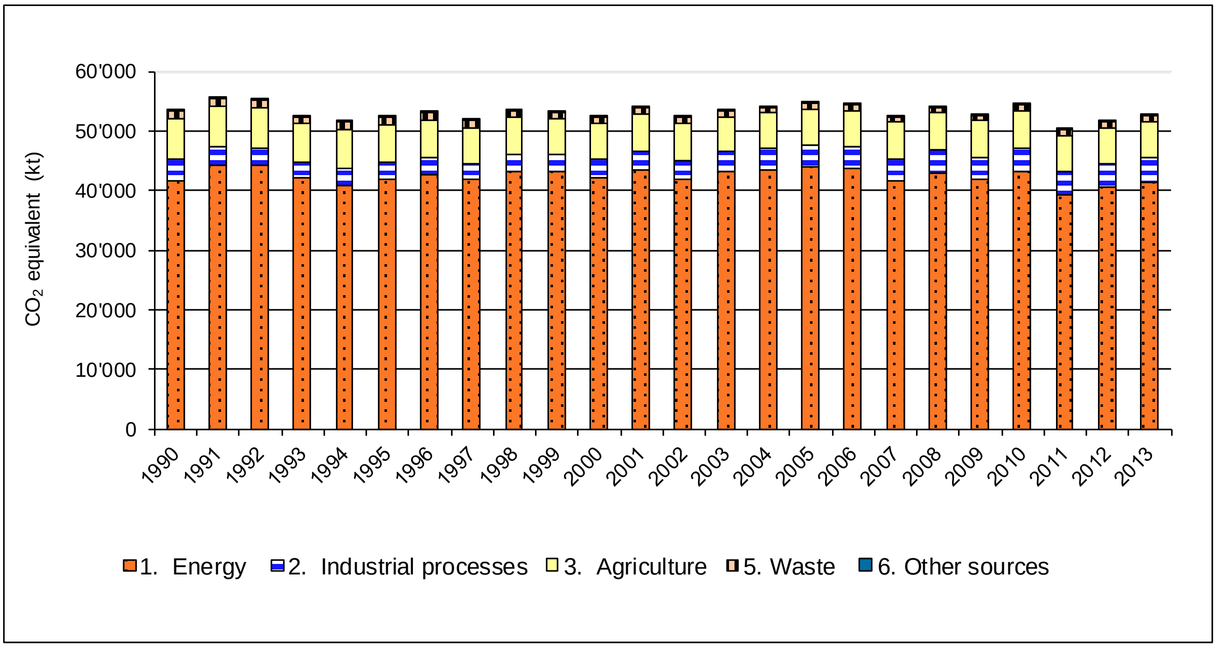


Figure E- 2 Switzerland's greenhouse gas emissions in CO_2 equivalent (kt) by main source categories, 1990–2013 (excluding LULUCF).

Table E- 6 shows the contributions of individual sectors to total emissions including LULUCF for selected years in more detail. Between 1990 and 2013, the relative contribution of sector 1 Energy decreased marginally from 82.8% to 80.5%, whereas emissions from sector 3 Agriculture decreased from 13.3% to 11.5% and those from sector 5 Waste changed from 2.7% to 2.0%. Sector 2 Industrial processes contributed 7.0% to total emissions in 1990 and 7.9 % in 2013, but with lower values in between (1995, 2000). The net sink of sector LULUCF decreased from -5.9% to -2.0%.

Table E- 6 Switzerland's total gross GHG emissions (including LULUCF) in CO_2 equivalent (kt) and the contribution of individual source categories, selected years.

Source and Sink Categories	1990		1995		2000		2005	
	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%
1. Energy	41'707	82.8%	41'803	85.9%	42'061	81.2%	43'918	84.0%
1A1 Energy industries	*2'558*	*5.1%*	2'698	*5.5%*	3'216	*6.2%*	3'840	*7.3%*
1A2 Manufacturing industries and construction	*6'260*	*12.4%*	6'069	*12.5%*	5'775	*11.1%*	5'885	*11.3%*
1A3 Transport	*14'613*	*29.0%*	14'229	*29.2%*	15'900	*30.7%*	15'838	*30.3%*
1A4 Other sectors	*17'666*	*35.1%*	18'200	*37.4%*	16'660	*32.2%*	17'923	*34.3%*
1A5 Other	*206*	*0.4%*	148	*0.3%*	136	*0.3%*	123	*0.2%*
1B Fugitive emissions from fuels	*405*	*0.8%*	459	*0.9%*	373	*0.7%*	308	*0.6%*
2. Industrial processes	3'522	7.0%	2'873	5.9%	3'098	6.0%	3'775	7.2%
3. Agriculture	6'713	13.3%	6'413	13.2%	6'029	11.6%	5'993	11.5%
4. Land use, land-use change and forestry and harvested wood products	-2'953	-5.9%	-3'590	-7.4%	-437	-0.8%	-2'359	-4.5%
5. Waste	1'355	2.7%	1'173	2.4%	1'046	2.0%	935	1.8%
6. Other sources	12	0.0%	13	0.0%	14	0.0%	14	0.0%
Total (including LULUCF and HWP)	50'355	100.0%	48'686	100.0%	51'810	100.0%	52'276	100.0%

Source and Sink Categories	2010		2011		2012		2013	
	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%
1. Energy	43'192	82.6%	39'145	82.3%	40'525	81.2%	41'452	80.5%
1A1 Energy industries	3'873	7.4%	3'620	*7.6%*	3'653	*7.3%*	3'678	*7.1%*
1A2 Manufacturing industries and construction	5'718	*10.9%*	5'271	*11.1%*	5'267	*10.6%*	5'377	*10.4%*
1A3 Transport	16'340	*31.2%*	16'224	*34.1%*	16'352	*32.8%*	16'245	*31.5%*
1A4 Other sectors	16'856	*32.2%*	13'645	*28.7%*	14'886	*29.8%*	15'768	*30.6%*
1A5 Other	121	*0.2%*	108	*0.2%*	116	*0.2%*	117	*0.2%*
1B Fugitive emissions from fuels	283	*0.5%*	276	*0.6%*	251	*0.5%*	267	*0.5%*
2. Industrial processes	4'017	7.7%	4'051	8.5%	4'056	8.1%	4'093	7.9%
3. Agriculture	6'108	11.7%	6'052	12.7%	6'015	12.1%	5'949	11.5%
4. Land use, land-use change and forestry and harvested wood products	-2'005	-3.8%	-2'685	-5.6%	-1'731	-3.5%	-1'036	-2.0%
5. Waste	981	1.9%	983	2.1%	1'013	2.0%	1'053	2.0%
6. Other sources	14	0.0%	14	0.0%	14	0.0%	14	0.0%
Total (including LULUCF and HWP)	52'307	100.0%	47'559	100.0%	49'892	100.0%	51'525	100.0%

ES.3.2 KP-LULUCF Activities

An overview of net CO_2 equivalent emissions and removals of activities under Article 3, paragraph 3 and Forest Management under paragraph 4 of the Kyoto Protocol is shown in Table E- 7. In 2013, Deforestations were responsible for an emission of 116.92 kt CO_2 equivalent, whereas Afforestations stored -14.32 kt CO_2 equivalent. Forest Management generates removals of -2290.87 kt CO_2 equivalent and harvested wood products -147.91 kt CO_2 equivalent.

Detailed quantitative information of the years 1999–2013 are reported in Chapter 11.4, Chapter 11.5 and displayed in Table 11-4. Annual changes in the emissions from Deforestation can directly be attributed to the changes in the area of Deforestations. Year-to-year fluctuations in removals from Afforestations are mainly due to changes in the yearly afforested area and the application of an exponential growth curve for Afforestations. Fluctuations in the contribution of Forest Management can mainly be explained by differences in the losses of living (cut and mortality) and dead biomass (dead wood and litter), whereas changes in the area of managed forest are relatively small. Fluctuations in the HWP-pool can mainly be attributed to changes in the production of sawn wood (see Chapter 6.11), which is strongly linked with the domestic harvesting rate in Swiss forests.

Table E- 7 Emissions (positive sign) and removals (negative sign) in the carbon pools under Activities under Article 3, paragraph 3 and paragraph 4 (Forest Management and HWP) of the Kyoto Protocol, kt CO_2 eq., 1999-2013. Used abbreviations explained in Chapter 6.1.3.2; C_{l_ag}: C above-ground living biomass; C_{l_bg}: C below-ground living biomass; C_h: C in litter, C_{s_md}: C in dead wood, C_{s_m}: C in mineral soil; C_{s_o}: C in organic soil.

Greenhouse gas source and sink activities	1999	2000	2001	2002	2003	2004	2005	2006
	Net CO_2 equivalent emissions/removals (kt CO_2 eq)							
Article 3.3 activities	**156.42**	**155.78**	**154.64**	**153.42**	**152.21**	**151.32**	**124.96**	**102.44**
A.1. Afforestation and Reforestation	-10.99	-11.42	-11.86	-12.29	-12.73	-13.16	-13.89	-14.49
A.2. Deforestation	167.41	167.20	166.49	165.71	164.94	164.48	138.85	116.92
Article 3.4 activities	**-3498.60**	**-912.40**	**-131.65**	**31.34**	**-2636.09**	**-3213.44**	**-3179.49**	**-2834.15**
B.1. Forest Management incl. biomass burning	-3013.06	-74.89	450.67	484.87	-2187.34	-2569.04	-2407.81	-2200.73
$gainC_{l\_ag}$	-9698.84	-9705.57	-9712.30	-9719.03	-9725.76	-9732.50	-9747.02	-9836.02
$gainC_{l\_bg}$	-2757.69	-2760.25	-2762.81	-2765.37	-2767.93	-2770.49	-2780.04	-2808.99
$lossC_{l\_ag}$	7758.49	10051.46	10371.07	10243.35	8273.15	8004.26	8375.33	8472.02
$lossC_{l\_bg}$	2253.94	2849.44	2927.38	2896.28	2394.55	2321.72	2428.41	2409.11
$changeC_h$	-324.83	-266.67	-169.85	-34.73	-204.30	-211.57	-455.64	-230.67
$changeC_d$	-280.50	-280.49	-239.68	-190.84	-219.72	-215.71	-264.99	-244.48
$changeC_{s\_m}$	-1.82	-2.35	-2.74	-2.97	-3.19	-3.56	-4.06	-4.61
$changeC_{s\_o}$	37.73	37.75	37.77	37.78	37.80	37.82	37.85	37.90
biom. burning	0.45	1.79	1.84	20.40	28.06	1.00	2.34	5.03
C. HWP	-485.54	-837.52	-582.32	-453.53	-448.75	-644.41	-771.69	-633.43

Greenhouse gas source and sink activities	2007	2008	2009	2010	2011	2012	2013	2014
	Net CO_2 equivalent emissions/removals (kt CO_2 eq)							
Article 3.3 activities	**80.00**	**53.04**	**117.45**	**145.20**	**146.21**	**147.14**	**147.60**	
A.1. Afforestation and Reforestation	-15.04	-15.53	-15.96	-15.34	-14.78	-14.29	-14.32	
A.2. Deforestation	95.04	68.56	133.42	160.55	160.99	161.43	161.92	
Article 3.4 activities	**-2378.67**	**-1972.23**	**-2483.02**	**-3210.84**	**-2969.82**	**-2960.34**	**-2448.94**	
B.1. Forest Management incl. biomass burning	-1636.91	-1447.67	-2003.56	-2701.27	-2600.01	-2660.79	-2290.79	
$gainC_{l\_ag}$	-9951.58	-10055.53	-10067.57	-10071.85	-10076.08	-10080.31	-10084.47	
$gainC_{l\_bg}$	-2845.83	-2879.37	-2883.61	-2885.61	-2887.44	-2889.28	-2891.10	
$lossC_{l\_ag}$	8807.35	8856.67	8481.49	8251.90	8204.50	8118.54	8139.59	
$lossC_{l\_bg}$	2512.57	2543.80	2454.51	2404.90	2400.63	2380.71	2582.65	
$changeC_h$	33.07	307.28	272.44	-55.08	48.35	72.92	175.68	
$changeC_d$	-237.28	-256.51	-296.59	-380.53	-331.87	-298.01	-247.89	
$changeC_{s\_m}$	-4.79	-4.63	-4.32	-4.25	-4.42	-4.48	-4.46	
$changeC_{s\_o}$	37.94	37.97	38.00	38.00	38.01	38.02	38.03	
biom. burning	11.64	2.64	2.09	1.24	8.31	1.09	1.18	
C. HWP	-741.76	-524.55	-479.46	-509.57	-369.81	-299.55	-158.15	

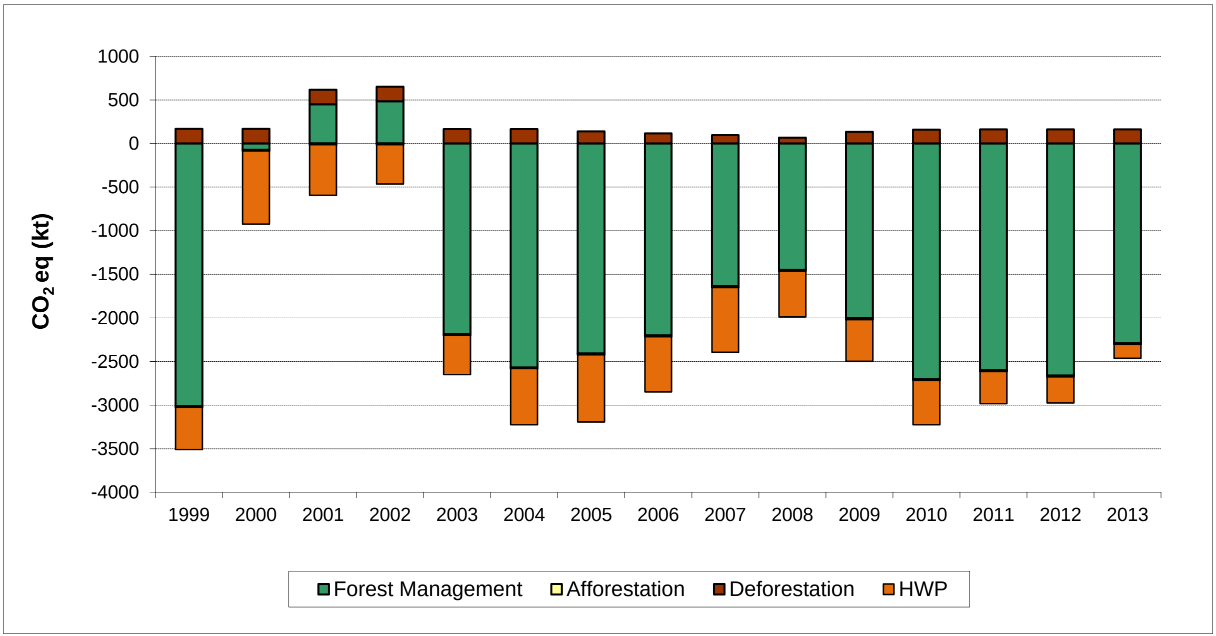


Figure E- 3 Emissions (positive sign) and removals (negative sign) of CO_2 eq from Afforestation and Deforestation under Article 3, paragraph 3 and Forest Management and HWP under Article 3, paragraph 4, 1999-2013.

ES.3.3 GHG Inventory (Kyoto Protocol)

Relevant emissions and removals under the Kyoto Protocol are shown in Table E- 8 and Table E- 9, sorted by sectors and gases respectively. The reported total emissions differ from those reported under the UNFCCC, as sector 6 Other – in addition to LULUCF and international bunkers – is not accounted for under the Kyoto Protocol. On the other hand, activities under article 3.3 (Afforestation, Reforestation and Deforestation) and 3.4 (Forest, Cropland and Grazing Management and Revegetation) are included in the tables. Under the elective voluntary activities of Article 3, paragraph 4 of the Kyoto Protocol, Switzerland only accounts for Forest Management. Base year emissions (as shown in Table E- 8 and Table E- 9), which are relevant to calculate the cap on activities under Art. 3.4 (see decision 2/CMP.7, paragraph 13), will be reported in the Second Initial Report (FOEN 2015e).

Table E- 8 Summary of Switzerland's GHG emissions in CO_2 equivalent (kt), 1990–2013 excluding emissions from sectors LULUCF, Other and International bunkers.

		Sector	Base year inital report	1990	1991	1992	1993	1994	1995	1996	1997	1998
			CO_2 equivalent (kt)									
Annex A sources		1 Energy	41'707	41'707	44'177	44'207	42'026	40'890	41'803	42'717	41'749	43'298
		2 Industrial processes	3'522	3'522	3'157	2'997	2'691	2'881	2'873	2'749	2'666	2'782
		3 Agriculture	6'713	6'713	6'674	6'557	6'456	6'440	6'413	6'367	6'182	6'141
		5 Waste	1'355	1'355	1'354	1'324	1'253	1'181	1'173	1'142	1'126	1'103
		Total (Annex A sources)	**53'296**	**53'296**	**55'362**	**55'085**	**52'425**	**51'392**	**52'262**	**52'974**	**51'723**	**53'324**

		Sector	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
			CO_2 equivalent (kt)									
Annex A sources		1 Energy	43'093	42'061	43'489	41'892	43'109	43'457	43'918	43'567	41'526	42'886
		2 Industrial processes	2'845	3'098	3'198	3'235	3'327	3'621	3'775	3'757	3'823	3'904
		3 Agriculture	6'055	6'029	6'089	6'054	5'976	5'954	5'993	6'022	6'076	6'180
		5 Waste	1'076	1'046	1'013	999	947	948	935	960	984	974
		Total (Annex A sources)	**53'068**	**52'233**	**53'789**	**52'180**	**53'359**	**53'979**	**54'621**	**54'305**	**52'408**	**53'943**
KP-LULUCF	Art.3.3	Afforestation & reforestation										-16
		Deforestation										69
	Art.3.4	Forest management										-1'448
		Cropland management										NA
		Grazing land management										NA
		Revegetation										NA
		Harvested wood products (HWP)										-524
		Total (Art. 3.3 + 3.4)										**-1'919**

		Sector	2009	2010	2011	2012	2013	Base year - 2013
			CO_2 equivalent (kt)					%
Annex A sources		1 Energy	41'815	43'192	39'145	40'525	41'452	-1%
		2 Industrial processes	3'796	4'017	4'051	4'056	4'093	16%
		3 Agriculture	6'091	6'108	6'052	6'015	5'949	-11%
		5 Waste	959	981	983	1'013	1'053	-22%
		Total (Annex A sources)	**52'662**	**54'297**	**50'230**	**51'608**	**52'547**	**-1.4%**
KP-LULUCF	Art.3.3	Afforestation & reforestation	-16	-15	-15	-14	-14	
		Deforestation	133	161	161	161	162	
	Art.3.4	Forest management	-2'004	-2'701	-2'600	-2'661	-2'291	
		Cropland management	NA	NA	NA	NA	NA	
		Grazing land management	NA	NA	NA	NA	NA	
		Revegetation	NA	NA	NA	NA	NA	
		Harvested wood products (HWP)	-479	-509	-370	-299	-158	
		Total (Art. 3.3 + 3.4)	**-2'365**	**-3'065**	**-2'823**	**-2'813**	**-2'301**	

Table E- 9 Switzerland's total GHG emissions (excluding LULUCF, Other and International bunkers) and the contribution of individual gases in CO_2 equivalent (kt), 1990-2013.

		GHG	Base year inital report	1990	1991	1992	1993	1994	1995	1996	1997	1998
			CO_2 equivalent (kt)									
Annex A sources		CO_2	44'020	44'020	46'090	45'961	43'545	42'581	43'341	44'076	42'967	44'527
		CH_4	6'168	6'168	6'185	6'071	5'945	5'885	5'864	5'794	5'648	5'568
		N_2O	2'854	2'854	2'847	2'815	2'748	2'717	2'702	2'697	2'601	2'596
		HFCs	0	0	2	16	33	82	246	297	361	456
		PFCs	117	117	99	81	35	21	17	20	21	24
		SF_6	137	137	139	141	121	107	93	90	124	153
		NF_3	0	0	0	0	0	0	0	0	0	0
		Total (Annex A sources)	**53'296**	**53'296**	**55'362**	**55'085**	**52'425**	**51'392**	**52'262**	**52'974**	**51'723**	**53'324**

		GHG	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
			CO_2 equivalent (kt)									
Annex A sources		CO_2	44'351	43'490	44'966	43'353	44'561	45'124	45'718	45'330	43'328	44'645
		CH_4	5'462	5'370	5'358	5'288	5'176	5'127	5'137	5'172	5'192	5'276
		N_2O	2'559	2'554	2'570	2'546	2'498	2'456	2'448	2'448	2'473	2'497
		HFCs	530	625	723	802	897	1'020	1'071	1'118	1'194	1'245
		PFCs	26	50	28	33	62	65	44	52	49	58
		SF_6	140	144	145	158	165	186	203	186	172	222
		NF_3	0	0	0	0	0	0	0	0	0	0
		Total (Annex A sources)	**53'068**	**52'233**	**53'789**	**52'180**	**53'359**	**53'979**	**54'621**	**54'305**	**52'408**	**53'943**
KP-LULUCF	Art.3.3	CO_2										-471
		CH_4										NO
		N_2O										0
	Art.3.4	CO_2										-1'454
		CH_4										1
		N_2O										5
		Total (Art. 3.3 + 3.4)										**-1'919**

		GHG	2009	2010	2011	2012	2013	base year - 2013
			CO_2 equivalent (kt)					%
Annex A sources		CO_2	43'512	45'037	40'970	42'229	43'160	-2%
		CH_4	5'188	5'195	5'152	5'151	5'147	-17%
		N_2O	2'460	2'509	2'459	2'454	2'415	-15%
		HFCs	1'253	1'335	1'415	1'495	1'520	NA
		PFCs	63	65	68	71	52	-55%
		SF_6	180	148	160	209	252	84%
		NF_3	5	8	6	0	0	NA
		Total (Annex A sources)	**52'662**	**54'297**	**50'230**	**51'608**	**52'547**	**-1.4%**
KP-LULUCF	Art.3.3	CO_2	-361	-364	-223	-152	-10	
		CH_4	NO	NO	NO	NO	NO	
		N_2O	0.0	0.0	0.0	0.0	0.0	
	Art.3.4	CO_2	-2'009	-2'707	-2'609	-2'666	-2'296	
		CH_4	0.9	0.6	3.8	0.5	0.5	
		N_2O	4.8	4.7	5.3	4.7	4.7	
		Total (Art. 3.3 + 3.4)	**-2'365**	**-3'065**	**-2'823**	**-2'813**	**-2'301**	

ES.4. Other information

Emission trends for indirect greenhouse gases show a very pronounced decline (see Table 2-6 and Figure 2-9). A strict air pollution control policy and the implementation of a large number of emission reduction measures led to a decrease of 51% to 75% in the period 1990-2013 in emissions of air pollutants. The main reduction measures were abatement of exhaust emissions from road vehicles and stationary combustion equipment, taxation of solvents and sulphured fuels, and voluntary agreements with industry sectors (FOEN 2010i, Swiss Confederation 1985, 1997).

Acknowledgements

The GHG inventory preparation is a joint effort which is based on input from many federal agencies, institutions, associations, companies and individuals. Their effort was essential for the successful completion of the present inventory report.

The Federal Office for the Environment would like to acknowledge the valuable support it has received from the many contributors to this document. In particular, it would like to thank all the data suppliers, including the Office of Environmental Protection of the Principality of Liechtenstein for providing its fossil fuel consumption data, as well as experts, authors and both national and international reviewers.

PART 1

1 Introduction

1.1 Background Information on Swiss Greenhouse Gas Inventories, Climate Change and Supplementary Information of the Kyoto Protocol (KP)

1.1.1 Information on Climate Change

The report of the Swiss Advisory Body on Climate Change (OcCC) provides an assessment of the observed and expected impacts of climate change on Switzerland and the vulnerability of various ecological and socio-economic systems (OcCC 2008). In the course of the 21st century, Swiss climate is projected to depart significantly from present and past conditions (CH2011 2011). Recent data confirms a warming trend with an observed increase in mean annual temperature of 1.75°C between 1864 and 2012 (FOEN 2014d). Over the last 100 years, mean annual temperatures increased by 0.13-0.20°C per decade, with a substantially accelerated warming in recent decades. According to the non-intervention scenarios (A2, A1B), seasonal mean temperatures will rise by another 2.7 - 4.8 °C by the end of this century compared to the period 1980-2009. Under the climate stabilization scenario (RCP3PD), Swiss climate would still change over the next decades, but is projected to stabilize at a mean warming of 1.2-1.8°C (FOEN 2014d).

The most visible change in the Alps resulting from global warming is the retreat of glaciers, which showed a volume loss of 12% since 1999 (FOEN 2014d). The area covered by alpine glaciers continuously diminishes. From about 2’900 km^2 of Alpine glacier area in the mid-1970s, only 2’100 km^2 remained in 2003 and an estimated 1’900 km^2 in 2013. A dramatic future loss in glacier covered area of 50-90% by 2100 has recently been modelled for a temperature increase of 2 - 6°C for Switzerland (FOEN 2014d).

The observed trends in precipitation are less distinct than in temperature. Compared to the last 30 years, and depending on the scenario considered, the best estimates of summer mean precipitation for all Swiss regions is projected to decrease by 8-28% over the 21st century. Uncertainties due to climate model imperfections and natural variability typically amount to 15% in precipitation (CH 2011 2011). The change in summer mean precipitation will have a marked impact on the hydrological cycle: on the Central Plateau and in the very south of Switzerland, small and medium watercourses will dry up more frequently and natural replenishment of groundwater will decrease accordingly. Apart from changes to the mean temperature and precipitation, the nature of extreme events is also expected to change (CH2011 2011). More frequent, intense and longer-lasting summer warm spells and heat waves are expected, while the number of cold winter days and nights decrease in the projections for future climate in Switzerland. This is particularly relevant for alpine areas, tourism and forestry due to the risk of more frequent floods, landslides and debris flows.

The warming trend and changing precipitation patterns are expected to have significant effects on ecosystems. The Biodiversity Monitoring Switzerland reports that impacts of climate change are already being observed. A report about climate change in Switzerland summarizes several climate change affected indicators such as the phenological spring phases, flowering indices and animal specific indices (FOEN 2014d). The indicators show significant changes in a wide range of ecosystems during the last decades. The report also emphasizes that typical alpine vascular plants have shifted uphill over the past century.

Generally, climate change is expected to affect species composition, distribution, their cycles, synchronicity, the overall genetic diversity and the provision of ecosystem services. It will enhance the vulnerability of forests and impair their protective, productive and social functions. For agriculture, a moderate warming of 2 - 3°C might increase productivity, however, if temperature will rise beyond that level, the increase in heat waves and drought periods would prove problematic for the cultivation of land and for livestock husbandry.

Various sectors of the Swiss economy are likely to be affected by progressing climate change. In particular, the tourism industry will be hit, as the potentially beneficial effects for summer tourism will not compensate for the loss of income in mountain resorts during winter due to scarcity of snow. Cable car stations may lose their stability due to instabilities of permafrost soils. Hydroelectric power stations may be affected by altered runoff and sediment transport regimes, and insurance companies may face increased losses due to winter storms and floods. Natural hazards and extreme weather events potentially pose a growing risk to infrastructure and human health. Heat waves and elevated tropospheric ozone levels are cause for serious concern, as evidenced by the impacts of the heat wave in 2003. Finally, it remains to be seen to what extent vector borne diseases spread due to changing climatic conditions. Recently Switzerland has analysed these challenges in detail and developed an effective adaptation strategy in order to hedge against negative effects resulting from climate change in Switzerland (FOEN 2012b).

1.1.2 Information on the Greenhouse Gas Inventory

On 10 December 1993, Switzerland ratified the United Nations Framework Convention on Climate Change (UNFCCC). Since 1996, the submission of its national greenhouse gas inventory has been based on IPCC guidelines. From 1998 onwards, the inventories have been submitted in the Common Reporting Format (CRF). In 2004, Switzerland started submitting an annual National Inventory Report (NIR) under the UNFCCC.

On 9 July 2003, Switzerland ratified the Kyoto Protocol under the UNFCCC. In November 2006 Switzerland submitted its Initial Report under Article 7, paragraph 4 of the Kyoto Protocol (FOEN 2006h). The Swiss National Inventory System (NIS) according to Article 5.1 of the Kyoto Protocol has been implemented in 2006 and is fully operational. On 6 December 2007, the NIS quality management system was certified to comply with ISO 9001:2000 requirements (SQS 2008); it has been audited and recertified in November 2010 and 2013. It includes the accounting and reporting of the National Registry as well (ISO 9001:2008, SQS 2010, Swiss TS 2013). The April 2008 submission of the Swiss GHG inventory (FOEN 2008) has been Switzerland’s first submission under both the UNFCCC and the Kyoto Protocol.

In 2015, Switzerland plans to ratify the Doha amendment to the Kyoto protocol and to submit the initial report for the second commitment period.

The 2015 inventory submission under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol has been restructured in accordance with the Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention (UNFCCC 2014a) and the Guidance for reporting information on activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol (UNFCCC 2014b). The submission will be made in two parts due to the problems with the UN software (CRF reporter). The first part includes the NIR on hand, the SEF tables and the standard independent assessment report (SIAR) from the National Registry. The second part will include the greenhouse gas inventory 1990–2013 and the Kyoto Protocol LULUCF tables 2008–2013 in the common reporting format.

1.1.3 Supplementary Information Required under Art. 7.1. KP

Chapter 11 of PART 2 as mentioned above provides information on KP-LULUCF.

Switzerland only accounts for the mandatory activity Forest Management under Article 3, paragraph 4 of the Kyoto Protocol (FOEN 2015e). In accordance with Annex I to Decision 2/CMP.7 (Annex I, Para 13), credits from Forest Management are capped in the second commitment period. Thus for Switzerland the cap amounts to 3.5% of the 1990 emissions (excluding LULUCF).

Switzerland has chosen to account over the entire commitment period for emissions and removals from activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol (FOEN 2015e). In addition to the mandatory submission of the inventory year 2013, data for the years 1999-2012 are available and shown in Switzerland's NIR.

1.2 National Inventory Arrangements

1.2.1 Institutional, Legal and Procedural Arrangements

Based on the Organisation Ordinance for the Federal Department of the Environment, Transport, Energy and Communications (DETEC), the Federal Office for the Environment (FOEN) is the designated national authority for climate policy and environmental monitoring. According to the decree of the Federal Council of 8 November 2006, the FOEN is in charge of the National Inventory System (NIS) (Figure 1-1). The Swiss National Inventory System was formally set up in 2006 in compliance with the requirements of the UNFCCC and the Kyoto Protocol (FOEN 2006h). In this context, the FOEN established the process "Climate Reporting", which covers maintaining the National Inventory System and fulfilling all reporting obligations under the UNFCCC and the Kyoto Protocol. The process, led and managed by the Climate division, is fully operational ever since and ensures timely fulfilment of Switzerland's reporting obligations.

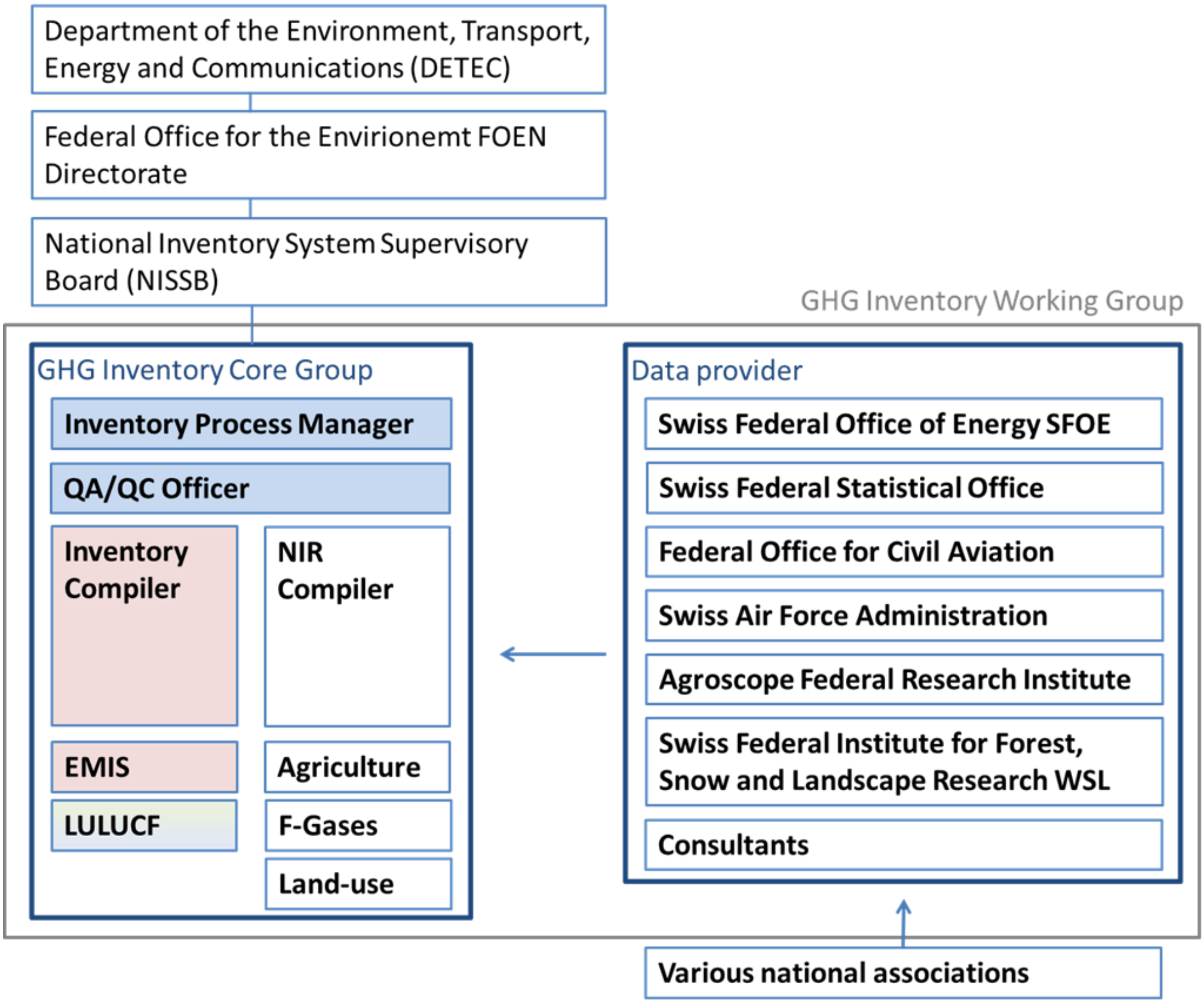


Figure 1-1 Institutional arrangements of the National Inventory System. Colours refer to divisions at FOEN. blue: Climate division, red: Air Pollution Control and Chemicals division, green: Forest division.

Legal arrangements

The CO2 act (Swiss Confederation 2011) and the CO_2 ordinance (Swiss Confederation 2012) are the main legal instruments regarding climate policies. They also define the implementing bodies and, for all measures that are regulated at the national level, sanctions for non-compliance to climate policies and measures. The FOEN plays a central role in the development, evaluation and implementation of policies and measures.

With regard to statistical investigations, the legal basis is laid down in the Federal Statistics Act (Swiss Confederation 1992a) and the corresponding Ordinance on the Conduct of Federal Statistical Surveys (Swiss Confederation 1993)). The greenhouse gas inventory, the institution responsible for it and the institutions contributing to it are explicitly listed in the ordinance.

Institutional arrangements

There are well-established agreements and long-standing collaborations with institutions of the federal administration and private entities (Table 1-1) that guarantee the continuity of the National Inventory System (Figure 1 1). While agreements with institutions of the federal administration are normally open-ended, several large contracts with private entities are on a four-year basis, with an option for renewal for another four-year term. This enables continuous collaboration and ensures the technical competence and experience of the staff involved.

The overall responsibility for the greenhouse gas inventory lies with the Climate division of the FOEN. The Air Pollution Control and Chemicals division of the FOEN maintains and updates the emissions database (greenhouse gas and air pollutants) in very close collaboration with the Climate division. The national energy statistics from the Federal Office of Energy (SFOE) provides the basis for the Energy sector. The Federal Office for Civil Aviation (FOCA) delivers the domestic and international aviation emissions. A consultancy (Carbotech) is mandated to survey and model fluorinated gases use and emissions and to provide an annual update thereof. Agriculture emissions are compiled by the federal research institute Agroscope. For LULUCF, detailed area survey data are provided by the Swiss Federal Statistical Office (SFSO). Two consultancies (Sigmaplan/Meteotest) are mandated to process the area survey data to derive land-use and land-use change data and related emissions. The Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) is in charge of the national forest inventory and forestry-related modelling, providing the relevant input for the Forest division of the FOEN, who is compiling forestry emissions and removals. The LULUCF sector is coordinated by a member of the Climate division of the FOEN. A collaboration between two consultancies (Infras/CSD) is mandated to update the National Inventory Report (NIR).

Single national entity with overall responsibility for the inventory

Federal Office for the Environment (FOEN)
Climate Division, Climate Reporting and Adaptation Section
Dr. Paul Filliger, process manager
CH-3003 Bern, Switzerland
+41 58 462 68 58
climate@bafu.admin.ch
www.climatereporting.ch

Table 1-1 Overview of the institutional arrangements

Institutions of the federal administration	
FOEN Climate division	Overall responsibitlity for the greenhouse gas inventory
FOEN Air Pollution Control and Chemicals division	EMIS data base and data archiving
FOEN Forest division	Forestry emissions and removals
Swiss Federal Office of Energy (SFOE)	Energy statistics
Federal Office of Civil Aviation (FOCA)	Aviation emissions
Swiss Federal Statistical Office (SFSO)	Area surveys for (KP-) LULUCF
Swiss Federal Institute for Forest, Snow and Landscape Research WSL	National forest inventory, forestry related modelling
Agroscope Federal Research Institute	Agriculture emissions and removals
Private entities	
Carbotech	Fluorinated gases emissions
Sigmaplan/Meteotest	(KP-) LULUCF
Infras/CSD	NIR editing, uncertainty analyses

1.2.2 Overview of Inventory Planning, Preparation and Management

The process of inventory planning, preparation and management in Switzerland is well-established. Responsibilities and decision-making power are assigned to specific people or groups of people (Figure 1-1). The management responsibility for the NIS lies with the **National Inventory System Supervisory Board** (NISSB). The board consists of a member of the FOEN directorate and FOEN division heads of the relevant divisions (Climate, Forest, Air Pollution Control and Chemicals, International Affairs). At the operational level, the process of planning, preparation and management of the greenhouse gas inventory is led by the **process manager**. The **QA/QC officer** oversees design, development, and operation of the quality management system and is the primary contact point during the UN review process. The **GHG inventory core group** is the committee that combines all technical expertise required for greenhouse gas inventory planning, preparation and management. It consists of the process manager, the QA/QC officer, the inventory compiler, sectoral experts, as well as the NIR compiler. Additional experts join the core group as required. The GHG inventory core group ensures conformity of the inventory with the relevant UNFCCC reporting guidelines (UNFCCC 2014a), timely inventory preparation, and consideration and approval of methodological changes, choice of data and recalculations. The **GHG inventory working group** encompasses all technical personnel involved in the inventory preparation process or representing institutions that play a significant role as suppliers of data.

Inventory planning, preparation, and management follow an annual cycle according to a plan-do-check-act cycle (Table 1-2). Planning of the inventory cycle starts with the first meeting of the GHG inventory core group in May, where work is scheduled, priorities with regard to inventory development are set and decisions regarding planned improvements are taken. Data compilation usually starts in June with the first data sets for the preceding year becoming available. Quality control activities form part of the data acquisition process. They are routinely carried out by the EMIS (emission database) experts and the sectoral experts. The UN review process in September provides further input to the inventory development plan. Recommendations and suggestions are discussed in the core group and future work is prioritized. The supervisory board (NISSB) is provided with the management review in October and asked for formal approval of the planned way of proceeding. An important stage in inventory preparation is the preparation and quality control of the CRF tables in December and January and the key-category and uncertainty analyses towards end of January. The editing of the National Inventory Report (NIR) progresses alongside data compilation, with a draft of the NIR going into internal review in March. Suggestions from the internal review are dealt with before submission as far as possible. If the internal review suggests large revisions, they are taken up in the inventory development plan for future improvements. The inventory is presented to the NISSB for official consideration and approval around end of March. Submission is coordinated by the process manager and carried out by the national inventory compiler. Archiving of inventory material is made after submission by the EMIS and sectoral experts, by the contributing authors and by the QA/QC officer.

Table 1-2 Annual cycle of inventory planning, preparation and management

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Data compilation												
QC EMIS Experts												
QC Sectoral Experts												
UN Review												
Inventory Development Plan												
CRF Tables												
QC CRF Tables												
KCA / Uncertainties												
NIR												
Internal review NIR and CRF Tables												
Official consideration and approval												
Submission												x
Archiving												
Meeting of Core Group	x				x			x		x		
Meeting of Working Group											x	
Meeting of NIS Supervisory Board						x					x	

1.2.3 Quality Assurance, Quality Control and Verification Plan

The national inventory system has an established quality management system (QMS) that complies with the requirements of ISO 9001:2008. Certification has been obtained in 2007 and is upheld since through annual audits (Swiss TS 2013). The QMS is designed to comply with the UNFCCC reporting guidelines (UNFCCC 2014a) to ensure and continuously improve transparency, consistency, comparability, completeness, accuracy, and confidence in national GHG emission and removal estimates. The quality manual (FOEN, 2015a) - as required by ISO 9001 - contains all relevant information regarding the QMS. It is updated annually and available to all members of the GHG inventory core group.

General QC procedures

The general QC activities as described in Table 6.1 of the IPCC reporting guidelines (IPCC 2006) are implemented in the annual cycle of inventory compilation (Table 1-2). Routine annual quality control procedures comprise checks related to new data and database operations, spot-checks for transcription errors, correct use of conversion factors and units, and correct calculations. There are checklists for the most important sectoral data suppliers and EMIS database experts.

Integrity of the database is ensured by creating a new database for every single submission and comparing the results from the new database with those from the previous version. Consistency of data between categories is to a large extent ensured by the design of the database, where specific emission factors and activity data that apply to various categories are used jointly by all categories to calculate emissions.

Checks regarding the correct aggregation are done on initial set-up of the various aggregations. There are also automated checks implemented in the database in order to identify incorrect internal aggregation processes. In preparation of the current submission with the revised reporting guidelines, the internal structure of the database had to be adjusted. Therefore, a thorough comparison of aggregated data in the previous and the new structure have been carried out on an identical data set, allowing to identify and correct errors in the category allocation and aggregation schemes implemented in the database. The database structure will be maintained for the second commitment period, thus minimizing the risks for structural errors in subsequent submissions.

Recalculations are compiled in a document and made available to the members of the GHG inventory core group. The recalculations file is of great importance in the QC procedures regarding the CRF tables and in the preparation of the NIR. QC procedures regarding the CRF tables comprise a detailed comparison of the CRF tables of the previous submission with those of the current submission for the base year and the latest common year. In addition, the time-series consistency is incrementally checked by comparing the latest inventory year with the preceding year. Any exceptional deviations are investigated by the sectoral or the EMIS database experts. These checks are performed in a multi-step process, first by collaborators of the Climate division of FOEN and then, after the required changes were implemented by the EMIS experts, by the NIR authors. However, since the CRF reporter was not available in time for inventory preparation, these checks were made on database exports for the current year, which were compared to the CRF tables of last submission.

The NIR is subject to an internal review prior to submission. The review of every section is carried-out by personnel not involved in the preparation of the reviewed section, but who is familiar with the reporting under the UNFCCC. Archiving of the database and related internal documentation is carried-out by the inventory compiler, while any other material is archived on the internal data management system by the QA/QC officer. Publicly available material is published after submission on the website owned by the FOEN (www.climatereporting.ch).

Category-specific QC procedures

Whenever new emission factors are considered, they are compared to the IPCC default values and to the values used in previous years. If the values are based on better or more appropriate data and compare reasonably well with the IPCC default values (or if differences can be explained), the new values are presented to the core group for adoption in future inventories. Similarly, if new activity data have become available for a particular category, a comparison between existing and new activity data is made and if the new data provide a more consistent or more reliable basis for the inventory, they are again presented to the core group for inclusion in future inventories. Quite often, sectoral and/or EMIS experts commission research to look into a particular topic in more detail. Results from these mid- to long-term projects are presented to the inventory core group. The core group decides on how to best implement the results and documents the agreed procedure in the inventory development plan. The general procedures regarding category-specific QC is also described in the quality manual (FOEN 2015a), while specific activities are documented in the corresponding sectoral chapters.

Quality assurance procedures

As required by ISO 9001 there are periodic internal audits covering all processes. In addition, an external organisation is mandated to do the annual audit of the ISO 9001 quality management system.

Apart from these audits, there are expert peer reviews for specific sectors commissioned on a case-by-case basis. The results and suggestions for improvements from these reviews are discussed in the core group and specific tasks for future implementation are taken up into the inventory development plan. The most recent expert peer reviews covered the Industrial Processes (CSD 2013), LULUCF (VTI 2011) and Waste sector (Rytec 2010).

Likewise, recommendations and encouragements from the UNFCCC expert review teams are also added to the inventory development plan, discussed in the core group and implementation in future submissions planned. Specific actions resulting from suggestions from the ERT are listed in chapter 10 Recalculations.

Verification activities

In the energy sector, the standard verification activity carried out on an annual basis is the reference approach, as documented in chapter 3.2.1 of the NIR and CRF table 1.A(b).

In addition, the FOEN supports a long-term monitoring programme carried out by the Swiss Federal Laboratories for Materials Science and Technology (EMPA). In the frame of this programme continuous measurements of atmospheric concentrations of various halogenated gases are made at the high-Alpine research station Jungfraujoch (3580 m asl), from which Swiss emissions of some fluorinated greenhouse gases can be estimated. These data are compared with the emissions reported in the greenhouse gas inventory. The results are briefly summarized in Annex 5.

Currently, a research project is looking into developing an independent estimate of CH_4 emissions in Switzerland based on atmospheric CH_4 measurements and inverse modelling of atmospheric transport. The research project is on-going. Preliminary results show a very good agreement between modelled emissions and emission estimates according to the greenhouse gas inventory. Results will be presented to the core group and included in the NIR as appropriate.

Treatment of Confidentiality Issues

Nearly all of the data necessary to compile the Swiss GHG inventory are publicly available. There are, however, a few exceptions:

- (i) Emission data that refers to a single enterprise is in general confidential.
- (ii) The reporting of disaggregated emissions from F-gases is confidential (not confidential as aggregated data).
- (iii) In the civil aviation sub-sector one data source (FOCA 1991) has been marked confidential by the Federal Office of Civil Aviation (FOCA).
- (iv) Unpublished AREA land use statistics raw data have been temporarily classified confidential by the Swiss Federal Statistical Office (SFSO).

The FOEN collects the data needed for calculating emissions of HFCs, PFCs, NF3 and SF6 from private companies or industry associations. In the National Inventory Report, the activity data underlying emission estimates of HFCs, PFCs, NF3 and SF6 are only partly presented at the most disaggregated level for reasons of confidentiality. However, complete emissions are reported in aggregated tables.

Confidential data will be made available by the FOEN in line with the procedures agreed under the UNFCCC for the technical review of GHG inventories (UNFCCC 2015).

Public access to the Swiss Greenhouse Gas Inventory

FOEN operates a website (www.climatereporting.ch) where the Swiss GHG inventories (NIR, CRF-tables, QA/QC supplement, UNFCCC review reports), the Swiss national communications and other reports submitted to the UNFCCC and the Kyoto Protocol may be downloaded. On this website, most papers, internal reports, domestic reviews, Excel calculation sheets, and other difficult-to-access materials ('grey literature') quoted in the Swiss GHG inventory are provided online. The climate reporting homepage thus provides the option for public review.

1.2.4 Changes in the National Inventory Arrangements since Previous Submission

Changes to institutional, legal and procedural arrangements (24/CP.19, 22. (a)):

There are no changes to arrangements with other institutions of the federal administration. The agreements regarding responsibilities and deliverables are maintained.

However, for the second commitment period, the contracts with private companies were put out for tender. The tenders were won by the contractors that have already collaborated in inventory preparation during the first commitment period, except for the editing of the NIR, where the previous contractor teamed up with a new partner (see Table 1-1). The contracts are running for four years with an option to extend by another four years in order to guarantee continuity in inventory preparation. The contractor responsible for the fluorinated gases emissions is now also a member of the greenhouse gas inventory core group.

Furthermore, the National Inventory System Supervisory Board (NISSB), which originally not only covered the National Inventory System but also the National Registry, has been formally split in two separate boards with separate mandates and responsibilities. The NISSB is now overseeing all aspects related to reporting obligations under the UNFCCC (including reporting of the National Registry in the NIR). The Emission Registry Supervisory Board ERSB on the other hand deals with management issues related to the National Registry.

Changes in staff and capacity (24/CP.19, 22. (b)):

In the Climate division a collaborator who contributes to the reporting obligations under the UNFCCC and the Kyoto Protocol has been replaced. As described above under institutional arrangements, editing of the NIR has partly been handed over to a new contractor. However, the main partner remained the same, securing the long-term experience built up over the past years. Apart from that, no other personnel changes occurred.

Changes to national entity with overall responsibility for the inventory (24/CP.19, 22. (c)):

No changes.

Changes to the process of inventory planning (24/CP.19, 22.(d,e)/23./24.):

No changes.

Changes to the process of inventory preparation (24/CP.19, 25./26.):

Due to the new reporting guidelines and the new CRF-Reporter, changes in the EMIS database and its export functionality were required. As the CRF-Reporter lacked crucial functionality, there was no possibility to thoroughly test the interface between the EMIS database and the CRF-Reporter in due time. In order to carry on with inventory preparation in the regular annual cycle, handling of the CRF-Reporter had to be postponed. Work with the CRF-Reporter will be resumed when a version with resolved functionality problems will be available.

Changes to the process of inventory management (24/CP.19, 27.):

No changes.

1.3 Inventory Preparation and Data Collection, Processing, and Storage

An overview over the inventory preparation is given above and is schematically shown in Figure 1-1. Each sector has an assigned sectoral expert who is responsible for conformity with the relevant reporting guidelines, selection of appropriate methods and data sources, and collection, processing and updating of data (Figure 1-2).

For the sectors Energy, IPPU (excl. fluorinated gases) and Waste, data collection and processing is done by the Air Pollution Control and Chemicals division of the FOEN. The use of fluorinated gases and related emissions in the corresponding source categories of the IPPU sector are provided by Carbotech, a consultancy mandated to collect and process relevant data. For Agriculture, data collection and processing is provided by Agroscope, the federal research institute for agriculture. Land-use and land use change data from the Swiss Federal Statistical Office is compiled by Meteotest/Sigmaplan, in close collaboration with the Forest division of the FOEN. The Swiss Federal Institute for Forest, Snow and Landscape Research WSL provides further input, which is processed by the Forest Division. Emission and removal estimates from forest land are calculated by the Forest division of the FOEN.

All people responsible for data collection and processing in a particular sector are preparing their data for import into the National Air Pollution Database EMIS, which compiles all inventory data, including activity data and emission factors. EMIS was originally established in the late 1980s in order to record and monitor emissions of air pollutants, but it has since been extended to cover greenhouse gases and additional emission sources. The original EMIS database underwent a full redesign and a migration to a new software platform in 2005/2006. In preparation for the submission in 2015, all processes relevant to the GHG inventory have been restructured according to the 2006 IPCC Guidelines and the revised CRF tables.

The EMIS database as well as background information on activity data and emission factors are archived by the national inventory compiler for each submission. In the sectors where data collection is made by EMIS experts (e.g. Energy, IPPU, Waste), additional background information is compiled as appropriate (e.g. interim worksheets; references; rationale for choice of methods, data sources, activity data, emission factors). Whenever such documents are cited, they are labelled as “EMIS 2015/(NFR-Code)” in this report.

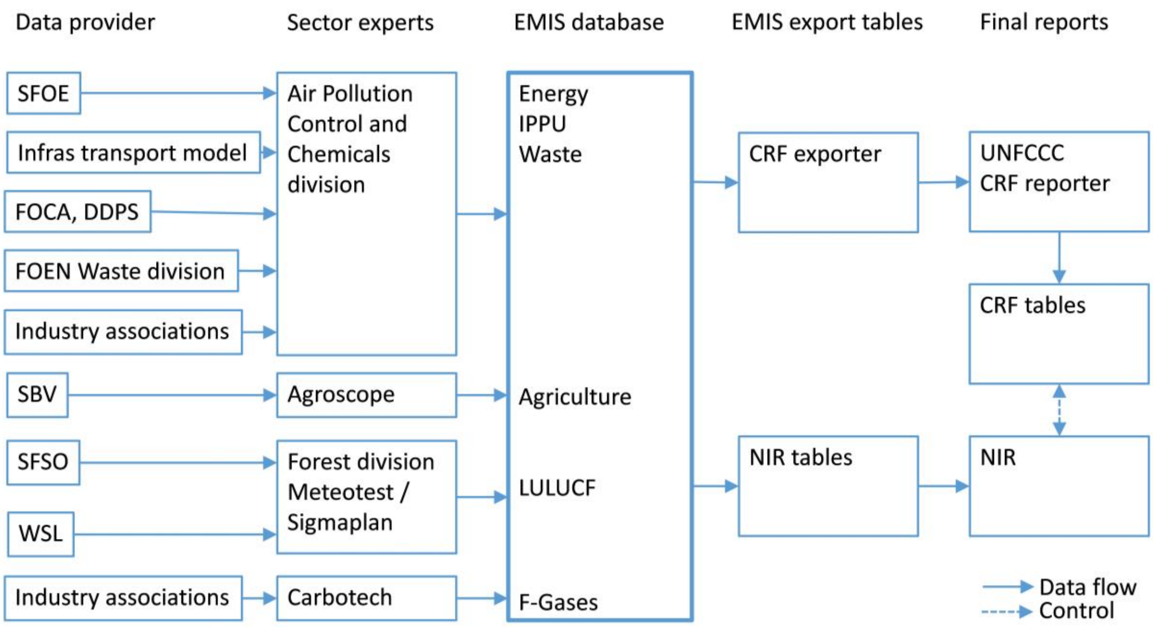


Figure 1-2 Schematic overview: Data collection and processing, compilation in EMIS database, export to CRF reporter and National Inventory Report (NIR). Abbreviations: see glossary.

1.4 Methodologies and Data Sources

According to the revised reporting guidelines under the UNFCCC (UNFCCC 2014a) and the Kyoto Protocol (UNFCCC 2014b), emissions are calculated based on standard methods and procedures provided in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006), the 2013 KP supplement (IPCC 2014), and the 2013 wetlands supplement (IPCC 2014a). All key categories are estimated using Approach 2 or higher or country-specific methods. The methodological tier used is described in detail in the sectoral chapters of the NIR and compiled in the CRF reporting table Summary 3.

Various data suppliers contribute to the greenhouse gas inventory (Table 1-3). While most data stem from official statistics either from the FOEN or from other federal offices, some data is drawn from national associations or consultancies that maintain well-established models or data-bases. Details on activity data and emission factors are provided in the sectoral chapters of the NIR.

Table 1-3 Primary data providers for the various inventory categories. Generally, statistics are updated annually. However, the on-road and off-road emission models of Infras, the complete area survey by the SFSO as well as the national forest inventory by the WSL require large efforts and are therefore updated every couple of years. Coloured boxes mark those sectors to which each data provider contributes. Abbreviations: see glossary

Institution	**Subject**	**Inventory category (numbering according to CRF tables)**										
		1A1	1A2	1A3	1A4	1A5	1B	2	3	4 / KP	5	6
FOEN, Air Pollution Control and Chemicals division	EMIS Database	■	■		■	■	■	■	■		■	■
FOEN, Clima	moitring data due to ordinance of red. of CO2 Confederation 2012)		■					■				
FOEN, Waste division	Waste Statistics	■	■								■	
INFRAS	On-road Emission Model			■								
INFRAS	Non-road Emission Model		■	■	■	■						
SFOE	Swiss overall energy statistics	■	■	■	■		■					
SFOE	Swiss statistics of renewable energies	■									■	
SFOE	Swiss wood energy statistics	■	■		■							
SFOE	Energy consumption in industry (helbling statistics)		■									
FOCA	Civil Aviation			■								
Swiss Air Force Administration (DDPS)	Military Aviation					■						
SGWA	Gas Distribution Losses						■					
Carbotech	F-gases, post-combustion of NMVOC							■				
Swissmem	National SF6 balance							■				
SFSO	Agriculture, LULUCF								■	■		
Agroscope	Agriculture, LULUCF								■	■		
SBV	Agriculture								■			
FOEN, Forest division	Forest Statistics									■		
WSL	National Forest Inventory									■		
Sigmaplan, Meteotest	LULUCF									■		

1.5 Description of Key Categories

1.5.1 GHG Inventory

1.5.1.1 Methodology

The key category analysis is performed according to the 2006 IPCC Guidelines (IPCC 2006, chapter 4) and Decision 24/CP.19 (UNFCCC 2014a, Annex 1, Para. 39) for 1990 and the latest reported year 2013. A total of 150 categories (see Annex A1.3 for details) are used to disaggregate Switzerland's total greenhouse gas emissions for the purpose of this key category analysis. Both, Approach 1 and Approach 2 level and trend assessments are applied, including emissions from sector 4 LULUCF. The uncertainty used to weigh emissions for the calculations under Approach 2 is the Approach 1 uncertainty (see chapter 1.7).

1.5.1.2 KCA (including LULUCF categories)

A complete overview of the key category analysis for the inventory 1990-2013, including also all categories which are not key, is given in Annex A1.3, table A-1. In the following, the results for Approach 1 and Approach 2 are presented, focussing on key categories only.

Approach 1

For 2013, among the total of 150 categories, 30 are identified as level key categories under Approach 1, with an aggregated level contribution of 95.2% to the total national emissions (Table 1-4).

Of the 30 key categories, 15 are in sector 1 Energy, accounting for 70.9% of total CO_2 equivalent emissions in 2013. The other key categories are from the sectors 2 Industrial processes (6.0%), 3 Agriculture (10.2%), 4 LULUCF (6.7%) and 5 Waste (1.5%).

There are three major key sources each contributing more than 10% to the level assessment:

- 1A3b Energy, Fuel Combustion, Road Transportation, Gasoline, CO_2, level contribution 15.1%
- 1A4b Energy, Fuel Combustion, Other Sectors, Residential, Liquid Fuels, CO_2, level contribution 12.8%
- 1A3b Energy, Fuel Combustion, Road Transportation, Diesel, CO_2, level contribution 12.5%

Table 1-4 Switzerland's Approach 1 level key categories for the year 2013 including LULUCF categories, sorted by emission contribution to the national total.

Approach 1 Key Category Analysis - Level Assessment for the year 2013								
No.	IPCC source categories and fuels if applicable				GHG	Year 2013 estimate [Gg CO2 eq]	Level assessment	Cumulative total of level assessment
1	1A3b	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	CO2	8608.76	15.1%	15.1%
2	1A4b	A. Fuel combustion activities	4. Other sectors; Residential	Liquid Fuels	CO2	7334.47	12.8%	27.9%
3	1A3b	A. Fuel combustion activities	3. Transport; Road transportation	Diesel	CO2	7137.84	12.5%	40.4%
4	1A4a	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Liquid Fuels	CO2	3286.01	5.7%	46.1%
5	3A	A. Enteric fermentation			CH4	3238.97	5.7%	51.8%
6	1A4b	A. Fuel combustion activities	4. Other sectors; Residential	Gaseous Fuels	CO2	2892.76	5.1%	56.8%
7	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Liquid Fuels	CO2	2274.91	4.0%	60.8%
8	4A1	A. Forest land	1. Forest land remaining forest land		CO2	-2258.41	3.9%	64.8%
9	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Gaseous Fuels	CO2	2255.42	3.9%	68.7%
10	1A1	A. Fuel combustion activities	1. Energy industries	Other Fuels	CO2	2228.12	3.9%	72.6%
11	2A1	A. Mineral industry	1. Cement production		CO2	1811.87	3.2%	75.8%
12	1A4a	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Gaseous Fuels	CO2	1572.39	2.7%	78.5%
13	2F1	F. Product uses as substitutes for ODS	1. Refrigeration and air conditioning		HFC	1396.88	2.4%	81.0%
14	3Da	D. Agricultural soils; Direct emissions from managed soils			N2O	1061.64	1.9%	82.8%
15	1A1	A. Fuel combustion activities	1. Energy industries	Liquid Fuels	CO2	945.83	1.7%	84.5%
16	4B1	B. Cropland	1. Cropland remaining cropland		CO2	842.28	1.5%	85.9%
17	3B	B. Manure management			CH4	759.58	1.3%	87.3%
18	1A4c	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Liquid Fuels	CO2	513.86	0.9%	88.2%
19	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Solid Fuels	CO2	490.74	0.9%	89.0%
20	3Db	D. Agricultural soils; Indirect emissions from managed soils			N2O	481.26	0.8%	89.9%
21	1A1	A. Fuel combustion activities	1. Energy industries	Gaseous Fuels	CO2	468.80	0.8%	90.7%
22	5B	B. Biological treatment of solid waste			CH4	468.63	0.8%	91.5%
23	4A2	A. Forest land	2. Land converted to forest land		CO2	-425.44	0.7%	92.2%
24	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Other Fuels	CO2	312.93	0.5%	92.8%
25	4E2	E. Settlements	2. Land converted to settlements		CO2	307.51	0.5%	93.3%
26	3B5	B. Manure management	5. Indirect N2O emissions		N2O	280.61	0.5%	93.8%
27	1B2	B. Fugitive emissions from fuels	2. Oil and natural gas and other emissions from ener		CH4	212.08	0.4%	94.2%
28	2G	G. Other product manufacture and use			SF6	198.21	0.3%	94.5%
29	5A	A. Solid waste disposal			CH4	191.70	0.3%	94.9%
30	5D	D. Wastewater treatment and discharge			CH4	173.34	0.3%	95.2%

For the base year 1990, 30 categories are identified as level key categories under Approach 1, with an aggregated level contribution of 95.1% to the total national emissions (Table 1-5). The following categories are key in 1990, but not in 2013:

- CO_2 emissions from 1A3a Energy, Domestic aviation
- CO_2 emissions from 1A5 Energy, Other, Liquid fuels
- CO_2 emissions from 2A4 Industrial processes, Other process uses of carbonates
- CO_2 emissions from 2C3 Industrial processes, Aluminium production
- CO_2 emissions from 4G LULUCF, Harvested wood products

On the other hand, the following categories are key in 2013, but not in 1990:

- CO_2 emissions from 1A2 Manufacturing industries and construction, Other fuels
- HFC emissions from 2F1 Industrial processes, Refrigeration and air conditioning
- SF_6 emissions from 2G Other product manufacture and use
- CH_4 emissions from Waste, Biological treatment of solid waste
- CH_4 emissions from Waste, Wastewater treatment and discharge

Table 1-5 Switzerland’s Approach 1 level key categories for the base year 1990 including LULUCF categories, sorted by emission contribution to the national total.

Approach 1 Key Category Analysis - Level Assessment for the base year 1990								
No.	IPCC source categories and fuels if applicable				GHG	Year 1990 estimate [Gg CO2 eq]	Level assessment	Cumulative total of level assessment
1	1A3b	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	CO2	11335.27	19.3%	19.3%
2	1A4b	A. Fuel combustion activities	4. Other sectors; Residential	Liquid Fuels	CO2	10099.18	17.2%	36.5%
3	1A4a	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Liquid Fuels	CO2	4260.88	7.3%	43.8%
4	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Liquid Fuels	CO2	3875.05	6.6%	50.4%
5	3A	A. Enteric fermentation			CH4	3511.54	6.0%	56.3%
6	1A3b	A. Fuel combustion activities	3. Transport; Road transportation	Diesel	CO2	2587.68	4.4%	60.7%
7	2A1	A. Mineral industry	1. Cement production		CO2	2524.45	4.3%	65.0%
8	4A1	A. Forest land	1. Forest land remaining forest land		CO2	-2342.87	4.0%	69.0%
9	1A1	A. Fuel combustion activities	1. Energy industries	Other Fuels	CO2	1491.55	2.5%	71.6%
10	1A4b	A. Fuel combustion activities	4. Other sectors; Residential	Gaseous Fuels	CO2	1458.04	2.5%	74.1%
11	3Da	D. Agricultural soils; Direct emissions from managed soils			N2O	1238.00	2.1%	76.2%
12	4G	G. Harvested wood products			CO2	-1218.45	2.1%	78.2%
13	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Solid Fuels	CO2	1155.82	2.0%	80.2%
14	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Gaseous Fuels	CO2	1057.12	1.8%	82.0%
15	1A4a	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Gaseous Fuels	CO2	984.01	1.7%	83.7%
16	5A	A. Solid waste disposal			CH4	923.53	1.6%	85.3%
17	3B	B. Manure management			CH4	908.04	1.5%	86.8%
18	1A1	A. Fuel combustion activities	1. Energy industries	Liquid Fuels	CO2	693.69	1.2%	88.0%
19	3Db	D. Agricultural soils; Indirect emissions from managed soils			N2O	658.05	1.1%	89.1%
20	4A2	A. Forest land	2. Land converted to forest land		CO2	-621.02	1.1%	90.2%
21	1A4c	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Liquid Fuels	CO2	547.34	0.9%	91.1%
22	4E2	E. Settlements	2. Land converted to settlements		CO2	394.80	0.7%	91.8%
23	4B1	B. Cropland	1. Cropland remaining cropland		CO2	364.73	0.6%	92.4%
24	1B2	B. Fugitive emissions from fuels	2. Oil and natural gas and other emissions from ener		CH4	319.73	0.5%	92.9%
25	1A1	A. Fuel combustion activities	1. Energy industries	Gaseous Fuels	CO2	276.38	0.5%	93.4%
26	1A3a	A. Fuel combustion activities	3. Transport; Domestic aviation		CO2	252.55	0.4%	93.8%
27	3B5	B. Manure management	5. Indirect N2O emissions		N2O	242.32	0.4%	94.2%
28	1A5	A. Fuel combustion activities	5. Other	Liquid Fuels	CO2	203.58	0.3%	94.6%
29	2A4	A. Mineral industry	4. Other process uses of carbonates		CO2	156.15	0.3%	94.9%
30	2C3	C. Metal industry	3. Aluminium production		CO2	139.26	0.2%	95.1%

Regarding the trend assessment between the base year 1990 and the most recent year 2013, 36 categories are identified as trend key categories under Approach 1, with an aggregated contribution of 95.1% to the trend assessment (Table 1-6).

Table 1-6 Switzerland’s Approach 1 trend key categories between 1990 and 2013 including LULUCF categories, sorted by contribution to the trend assessment.

Approach 1 Key Category Analysis - Trend Assessment										
No.	IPCC source categories and fuels if applicable				GHG	Base year 1990 estimate [Gg CO2 eq]	Year 2013 estimate [Gg CO2 eq]	Trend assessment	Contribution to trend [%]	Cumulative total of contribution to trend
1	1A3b	A. Fuel combustion activities	3. Transport; Road transportation	Diesel	CO2	2587.68	7137.84	0.07647	16.7%	16.7%
2	1A4b	A. Fuel combustion activities	4. Other sectors; Residential	Liquid Fuels	CO2	10099.18	7334.47	0.05108	11.2%	27.9%
3	1A3b	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	CO2	11335.27	8608.76	0.05092	11.1%	39.0%
4	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Liquid Fuels	CO2	3875.05	2274.91	0.02878	6.3%	45.3%
5	1A4b	A. Fuel combustion activities	4. Other sectors; Residential	Gaseous Fuels	CO2	1458.04	2892.76	0.02386	5.2%	50.6%
6	2F1	F. Product uses as substitutes for ODS	1. Refrigeration and air conditioning		HFC	0.02	1396.88	0.02379	5.2%	55.8%
7	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Gaseous Fuels	CO2	1057.12	2255.42	0.01999	4.4%	60.1%
8	1A4a	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Liquid Fuels	CO2	4260.88	3286.01	0.01829	4.0%	64.1%
9	4G	G. Harvested wood products			CO2	-1218.45	-147.91	0.01775	3.9%	68.0%
10	2A1	A. Mineral industry	1. Cement production		CO2	2524.45	1811.87	0.01313	2.9%	70.9%
11	5A	A. Solid waste disposal			CH4	923.53	191.70	0.01283	2.8%	73.7%
12	1A1	A. Fuel combustion activities	1. Energy industries	Other Fuels	CO2	1491.55	2228.12	0.01195	2.6%	76.3%
13	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Solid Fuels	CO2	1155.82	490.74	0.01178	2.6%	78.9%
14	1A4a	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Gaseous Fuels	CO2	984.01	1572.39	0.00963	2.1%	81.0%
15	4B1	B. Cropland	1. Cropland remaining cropland		CO2	364.73	842.28	0.00799	1.7%	82.7%
16	5B	B. Biological treatment of solid waste			CH4	81.83	468.63	0.00655	1.4%	84.2%
17	3A	A. Enteric fermentation			CH4	3511.54	3238.97	0.00603	1.3%	85.5%
18	1A1	A. Fuel combustion activities	1. Energy industries	Liquid Fuels	CO2	693.69	945.83	0.00402	0.9%	86.4%
19	3Da	D. Agricultural soils; Direct emissions from managed soils			N2O	1238.00	1061.64	0.00349	0.8%	87.1%
20	3Db	D. Agricultural soils; Indirect emissions from managed soils			N2O	658.05	481.26	0.00327	0.7%	87.9%
21	1A1	A. Fuel combustion activities	1. Energy industries	Gaseous Fuels	CO2	276.38	468.80	0.00317	0.7%	88.5%
22	4A2	A. Forest land	2. Land converted to forest land		CO2	-621.02	-425.44	0.00308	0.7%	89.2%
23	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Other Fuels	CO2	134.16	312.93	0.00299	0.7%	89.9%
24	3B	B. Manure management			CH4	908.04	759.58	0.00289	0.6%	90.5%
25	2C3	C. Metal industry	3. Aluminium production		CO2	139.26	0.00	0.00243	0.5%	91.0%
26	1A3a	A. Fuel combustion activities	3. Transport; Domestic aviation		CO2	252.55	132.29	0.00215	0.5%	91.5%
27	2C3	C. Metal industry	3. Aluminium production		PFC	116.46	0.00	0.00203	0.4%	92.0%
28	1A3b	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	N2O	136.89	22.82	0.00200	0.4%	92.4%
29	1B2	B. Fugitive emissions from fuels	2. Oil and natural gas and other emissions from ener		CH4	319.73	212.08	0.00196	0.4%	92.8%
30	4C2	C. Grassland	2. Land converted to grassland		CO2	49.75	159.18	0.00184	0.4%	93.2%
31	1A3b	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	CH4	116.05	21.00	0.00166	0.4%	93.6%
32	4E2	E. Settlements	2. Land converted to settlements		CO2	394.80	307.51	0.00164	0.4%	93.9%
33	1A5	A. Fuel combustion activities	5. Other	Liquid Fuels	CO2	203.58	115.64	0.00158	0.3%	94.3%
34	1A4b	A. Fuel combustion activities	4. Other sectors; Residential	Biomass	CH4	109.96	32.07	0.00137	0.3%	94.6%
35	2A4	A. Mineral industry	4. Other process uses of carbonates		CO2	156.15	85.84	0.00126	0.3%	94.9%
36	2G	G. Other product manufacture and use			HFC	0.00	66.15	0.00113	0.2%	95.1%

Approach 2

Given that the threshold is set at 90%, the number of key categories is smaller under Approach 2 compared to Approach 1. 21 out of 150 categories are identified for both 1990 and 2013 as key categories with an aggregated level contribution of 90.2% and 90.3% to the total national emissions, respectively (Table 1-7, Table 1-8).

Because of its large uncertainties, 4C1 Grassland remaining grassland (CO_2) solely contributes 23.1% to the level assessment. All other sources contribute less than 10% to the level assessment, out of which the following are the most relevant:

- 3DA Agricultural soils, direct emissions from managed soils, N_2O, level contribution 9.2%
- 4A1 Forest land remaining forest land, CO_2, level contribution 8.4%

Compared to the Approach 1 numerous categories are not key anymore under Approach 2. Nevertheless, the following two categories are only key under Approach 2 (year 2013):

- CO_2 emissions from 4C1, LULUCF, Grassland remaining grassland
- CO_2 emissions from 4C2, LULUCF, Land converted to grassland

Table 1-7 Switzerland's Approach 2 level key categories for the year 2013 including LULUCF categories, sorted by emission contribution to the national total.

Key categories resulting from Approach 2 Key Category Analysis											
No.	IPCC source categories and fuels if applicable					GHG	Year 2013 estimate [Gg CO2 eq]	Combined Uncertainty	Level assessment	Cumulative total of level assessment
1	4C1	4. LULUCF	C. Grassland	1. Grassland remaining grassland		CO2	121.07	2316.0%	23.1%	23.1%
2	3Da	3. Agriculture	D. Agricultural soils; Direct emissions from managed soils			N2O	1061.64	105.1%	9.2%	32.2%
3	4A1	4. LULUCF	A. Forest land	1. Forest land remaining forest land		CO2	-2258.41	45.0%	8.4%	40.6%
4	3Db	3. Agriculture	D. Agricultural soils; Indirect emissions from managed soils			N2O	481.26	177.2%	7.0%	47.6%
5	4B1	4. LULUCF	B. Cropland	1. Cropland remaining cropland		CO2	842.28	87.8%	6.1%	53.7%
6	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Other Fuels	CO2	2228.12	31.6%	5.8%	59.5%
7	3B5	3. Agriculture	B. Manure management	5. Indirect N2O emissions		N2O	280.61	244.5%	5.6%	65.1%
8	3A	3. Agriculture	A. Enteric fermentation			CH4	3238.97	18.1%	4.8%	69.9%
9	5B	5. Waste	B. Biological treatment of solid waste			CH4	468.63	100.5%	3.9%	73.8%
10	3B	3. Agriculture	B. Manure management			CH4	759.58	54.4%	3.4%	77.2%
11	2F1	2. Industrial processes and product use	F. Product uses as substitutes for ODS	1. Refrigeration and air conditioning		HFC	1396.88	16.6%	1.9%	79.1%
12	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Gaseous Fuels	CO2	2892.76	6.8%	1.6%	80.7%
13	4A2	4. LULUCF	A. Forest land	2. Land converted to forest land		CO2	-425.44	45.0%	1.6%	82.3%
14	4E2	4. LULUCF	E. Settlements	2. Land converted to settlements		CO2	307.51	50.2%	1.3%	83.6%
15	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Gaseous Fuels	CO2	2255.42	6.8%	1.3%	84.8%
16	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Solid Fuels	CO2	490.74	30.0%	1.2%	86.0%
17	4C2	4. LULUCF	C. Grassland	2. Land converted to grassland		CO2	159.18	72.7%	1.0%	87.0%
18	5A	5. Waste	A. Solid waste disposal			CH4	191.70	58.3%	0.9%	87.9%
19	1A4a	1. Energy	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Gaseous Fuels	CO2	1572.39	6.8%	0.9%	88.8%
20	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Other Fuels	CO2	312.93	31.6%	0.8%	89.6%
21	5D	5. Waste	D. Wastewater treatment and discharge			CH4	173.34	50.0%	0.7%	90.3%

Table 1-8 Switzerland's Approach 2 level key categories for the base year 1990 including LULUCF categories, sorted by emission contribution to the national total.

Key categories resulting from Approach 2 Key Category Analysis										
No.	IPCC source categories and fuels if applicable					GHG	Year 1990 estimate [Gg CO2 eq]	Combined Uncertainty	Level assessment	Cumulative total of level assessment
1	4C1	4. LULUCF	C. Grassland	1. Grassland remaining grassland		CO2	86.70	2316.0%	16.9%	16.9%
2	3Da	3. Agriculture	D. Agricultural soils; Direct emissions from managed soils			N2O	1238.00	105.1%	11.0%	27.9%
3	3Db	3. Agriculture	D. Agricultural soils; Indirect emissions from managed soils			N2O	658.05	177.2%	9.8%	37.7%
4	4A1	4. LULUCF	A. Forest land	1. Forest land remaining forest land		CO2	-2342.87	45.0%	8.9%	46.6%
5	4G	4. LULUCF	G. Harvested wood products			CO2	-1218.45	57.1%	5.9%	52.5%
6	3A	3. Agriculture	A. Enteric fermentation			CH4	3511.54	18.1%	5.4%	57.9%
7	3B5	3. Agriculture	B. Manure management	5. Indirect N2O emissions		N2O	242.32	244.5%	5.0%	62.9%
8	5A	5. Waste	A. Solid waste disposal			CH4	923.53	58.3%	4.5%	67.4%
9	3B	3. Agriculture	B. Manure management			CH4	908.04	54.4%	4.2%	71.6%
10	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Other Fuels	CO2	1491.55	31.6%	4.0%	75.5%
11	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Solid Fuels	CO2	1155.82	30.0%	2.9%	78.5%
12	4B1	4. LULUCF	B. Cropland	1. Cropland remaining cropland		CO2	364.73	87.8%	2.7%	81.2%
13	4A2	4. LULUCF	A. Forest land	2. Land converted to forest land		CO2	-621.02	45.0%	2.4%	83.5%
14	4E2	4. LULUCF	E. Settlements	2. Land converted to settlements		CO2	394.80	50.2%	1.7%	85.2%
15	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Gaseous Fuels	CO2	1458.04	6.8%	0.8%	86.0%
16	1B2	1. Energy	B. Fugitive emissions from fuels	2. Oil and natural gas and other emissions from energy production		CH4	319.73	30.0%	0.8%	86.8%
17	2G	2. Industrial processes and product use	G. Other product manufacture and use			N2O	105.87	80.0%	0.7%	87.5%
18	4 III	4. LULUCF	N mineralization			N2O	61.10	135.1%	0.7%	88.2%
19	5B	5. Waste	B. Biological treatment of solid waste			CH4	81.83	100.5%	0.7%	88.9%
20	2A4	2. Industrial processes and product use	A. Mineral industry	4. Other process uses of carbonates		CO2	156.15	51.0%	0.7%	89.6%
21	3B1-3B4	3. Agriculture	B. Manure management	1. Cattle, 2. Sheep, 3. Swine, 4. Other livestock		N2O	105.64	72.1%	0.6%	90.2%

Regarding the trend assessment between the base year 1990 and the most recent year 2013, 26 categories are identified as trend key categories under Approach 2, with an aggregated contribution of 90.4% to the trend assessment (Table 1-9).

Table 1-9 Switzerland's Approach 2 trend key categories between 1990 and 2013 including LULUCF categories, sorted by contribution to the trend assessment.

Approach 2 Key Category Analysis - Trend Assessment													
No.	IPCC source categories and fuels if applicable					GHG	Base year 1990 estimate [Gg CO2 eq]	Year 2013 estimate [Gg CO2 eq]	Combined Uncertainty	Trend assessment	Contribution to trend [%]	Cumulative total of contribution to trend
1	4C1	4. LULUCF	C. Grassland	1. Grassland remaining grassland		CO2	86.70	121.07	2316.0%	1.27605	14.2%	14.2%
2	4G	4. LULUCF	G. Harvested wood products			CO2	-1218.45	-147.91	57.1%	1.01311	11.2%	25.4%
3	5A	5. Waste	A. Solid waste disposal			CH4	923.53	191.70	58.3%	0.74802	8.3%	33.7%
4	4B1	4. LULUCF	B. Cropland	1. Cropland remaining cropland		CO2	364.73	842.28	87.8%	0.70149	7.8%	41.5%
5	5B	5. Waste	B. Biological treatment of solid waste			CH4	81.83	468.63	100.5%	0.65876	7.3%	48.8%
6	3Db	3. Agriculture	D. Agricultural soils; Indirect emissions from managed soils			N2O	658.05	481.26	177.2%	0.57947	6.4%	55.2%
7	2F1	2. Industrial processes and product use	F. Product uses as substitutes for ODS	1. Refrigeration and air conditioning		HFC	0.02	1396.88	16.6%	0.39431	4.4%	59.6%
8	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Other Fuels	CO2	1491.55	2228.12	31.6%	0.37801	4.2%	63.8%
9	3Da	3. Agriculture	D. Agricultural soils; Direct emissions from managed soils			N2O	1238.00	1061.64	105.1%	0.36728	4.1%	67.9%
10	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Solid Fuels	CO2	1155.82	490.74	30.0%	0.35350	3.9%	71.8%
11	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Gaseous Fuels	CO2	1458.04	2892.76	6.8%	0.16208	1.8%	73.6%
12	3B	3. Agriculture	B. Manure management			CH4	908.04	759.58	54.4%	0.15710	1.7%	75.3%
13	4A2	4. LULUCF	A. Forest land	2. Land converted to forest land		CO2	-621.02	-425.44	45.0%	0.13896	1.5%	76.9%
14	3B5	3. Agriculture	B. Manure management	5. Indirect N2O emissions		N2O	242.32	280.61	244.5%	0.13599	1.5%	78.4%
15	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Gaseous Fuels	CO2	1057.12	2255.42	6.8%	0.13581	1.5%	79.9%
16	4C2	4. LULUCF	C. Grassland	2. Land converted to grassland		CO2	49.75	159.18	72.7%	0.13399	1.5%	81.4%
17	3A	3. Agriculture	A. Enteric fermentation			CH4	3511.54	3238.97	18.1%	0.10931	1.2%	82.6%
18	1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	N2O	136.89	22.82	50.0%	0.09986	1.1%	83.7%
19	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Other Fuels	CO2	134.16	312.93	31.6%	0.09460	1.0%	84.7%
20	4D1	4. LULUCF	D. Wetlands	1. Wetlands remaining wetlands		CO2	3.14	55.61	104.4%	0.09316	1.0%	85.8%
21	2G	2. Industrial processes and product use	G. Other product manufacture and use			N2O	105.87	43.39	80.0%	0.08848	1.0%	86.7%
22	4E2	4. LULUCF	E. Settlements	2. Land converted to settlements		CO2	394.80	307.51	50.2%	0.08254	0.9%	87.7%
23	1A4a	1. Energy	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Gaseous Fuels	CO2	984.01	1572.39	6.8%	0.06543	0.7%	88.4%
24	2A4	2. Industrial processes and product use	A. Mineral industry	4. Other process uses of carbonates		CO2	156.15	85.84	51.0%	0.06422	0.7%	89.1%
25	1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	CH4	116.05	21.00	37.0%	0.06161	0.7%	89.8%
26	1B2	1. Energy	B. Fugitive emissions from fuels	2. Oil and natural gas and other emissions from energy production		CH4	319.73	212.08	30.0%	0.05879	0.7%	90.4%

1.5.1.3 Summary of combined KCA including LULUCF categories

A summary of the key category analysis for 2013 is shown in Table 1-10, considering level and trend assessments for both, Approach 1 and Approach 2.

Table 1-10 Summary of Switzerland's combined KCA Approach for 2013 including LULUCF categories. The abbreviations used in the last column indicate whether a certain category is identified as key because of the level assessment (L1 = level according to approach 1, L2 = level according to approach 2) or the trend assessment (T1 = trend according to approach 1, T2 = trend according to approach 2).

Summary of Key Category Analysis for Switzerland
Quantitative method used: Approach 1 and Approach 2 (2013)

No.	IPCC source categories and fuels if applicable				GHG	Identification criteria
1	1A1	A. Fuel combustion activities	1. Energy industries	Gaseous Fuels	CO2	L1, T1
2	1A1	A. Fuel combustion activities	1. Energy industries	Liquid Fuels	CO2	L1, T1
3	1A1	A. Fuel combustion activities	1. Energy industries	Other Fuels	CO2	L1, L2, T1, T2
4	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Gaseous Fuels	CO2	L1, L2, T1, T2
5	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Liquid Fuels	CO2	L1, T1
6	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Other Fuels	CO2	L1, L2, T1, T2
7	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Solid Fuels	CO2	L1, L2, T1, T2
8	1A3a	A. Fuel combustion activities	3. Transport; Domestic aviation		CO2	T1
9	1A3b	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	CH4	T1, T2
10	1A3b	A. Fuel combustion activities	3. Transport; Road transportation	Diesel	CO2	L1, T1
11	1A3b	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	CO2	L1, T1
12	1A3b	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	N2O	T1, T2
13	1A4a	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Gaseous Fuels	CO2	L1, L2, T1, T2
14	1A4a	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Liquid Fuels	CO2	L1, T1
15	1A4b	A. Fuel combustion activities	4. Other sectors; Residential	Biomass	CH4	T1
16	1A4b	A. Fuel combustion activities	4. Other sectors; Residential	Gaseous Fuels	CO2	L1, L2, T1, T2
17	1A4b	A. Fuel combustion activities	4. Other sectors; Residential	Liquid Fuels	CO2	L1, T1
18	1A4c	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Liquid Fuels	CO2	L1
19	1A5	A. Fuel combustion activities	5. Other	Liquid Fuels	CO2	T1
20	1B2	B. Fugitive emissions from fuels	2. Oil and natural gas and other emissions from energy produc		CH4	L1, T1, T2
21	2A1	A. Mineral industry	1. Cement production		CO2	L1, T1
22	2A4	A. Mineral industry	4. Other process uses of carbonates		CO2	T1, T2
23	2C3	C. Metal industry	3. Aluminium production		CO2	T1
24	2C3	C. Metal industry	3. Aluminium production		PFC	T1
25	2F1	F. Product uses as substitutes for ODS	1. Refrigeration and air conditioning		HFC	L1, L2, T1, T2
26	2G	G. Other product manufacture and use			HFC	T1
27	2G	G. Other product manufacture and use			SF6	L1
28	2G	G. Other product manufacture and use			N2O	T2
29	3A	A. Enteric fermentation			CH4	L1, L2, T1, T2
30	3B	B. Manure management			CH4	L1, L2, T1, T2
31	3B5	B. Manure management	5. Indirect N2O emissions		N2O	L1, L2, T2
32	3Da	D. Agricultural soils; Direct emissions from managed soils			N2O	L1, L2, T1, T2
33	3Db	D. Agricultural soils; Indirect emissions from managed soils			N2O	L1, L2, T1, T2
34	4A1	A. Forest land	1. Forest land remaining forest land		CO2	L1, L2
35	4A2	A. Forest land	2. Land converted to forest land		CO2	L1, L2, T1, T2
36	4B1	B. Cropland	1. Cropland remaining cropland		CO2	L1, L2, T1, T2
37	4C1	C. Grassland	1. Grassland remaining grassland		CO2	L2, T2
38	4C2	C. Grassland	2. Land converted to grassland		CO2	L2, T1, T2
39	4D1	D. Wetlands	1. Wetlands remaining wetlands		CO2	T2
40	4E2	E. Settlements	2. Land converted to settlements		CO2	L1, L2, T1, T2
41	4G	G. Harvested wood products			CO2	T1, T2
42	5A	A. Solid waste disposal			CH4	L1, L2, T1, T2
43	5B	B. Biological treatment of solid waste			CH4	L1, L2, T1, T2
44	5D	D. Wastewater treatment and discharge			CH4	L1, L2

1.5.2 KP-LULUCF Inventory

Switzerland identified four key categories for activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol (Forest Management, Afforestation and Reforestation, Deforestation, Harvested Wood Products). The approach relies on full inventory KCA (with LULUCF), KP - CRF association and qualitative assessment. A detailed description is presented in chapter 11.6.1 and in Table 11-3.

1.6 Completeness Assessment

1.6.1 GHG Inventory

For all known sources, complete estimates are accomplished for all gases. Based on current knowledge, the Swiss inventory under the UNFCCC is complete.

1.6.2 KP-LULUCF Inventory

For all known sources and sinks, complete estimates are accomplished for the current submission. The Swiss LULUCF inventory under the Kyoto Protocol is complete.

1.7 Uncertainty Evaluation

1.7.1 GHG Inventory

1.7.1.1 Approach 1 and Approach 2 analysis

This chapter presents the main results of the uncertainty evaluation Approach 1 and Approach 2 in accordance with the IPCC 2006 Guidelines (IPCC 2006):

- Approach 1: Propagation of error
- Approach 2: Monte Carlo simulation

All uncertainties are given as half of the 95% confidence interval divided by the mean and expressed as a percentage (approximately two standard deviations) as suggested by the IPCC Guidelines (IPCC 2006).

The uncertainty analyses Approach 1 and Approach 2 are updated yearly.

The following chapters present the overall results of the uncertainty evaluation. Specific information about the uncertainty estimation for activity data, emission factors or emissions of each source category is included in the respective sectoral chapters (3–9) below, and details of Approach 2 are presented in Annex 2.

1.7.1.2 Data Used

The evaluation includes uncertainties regarding activity data and emission factors. Uncertainties in the GWP values are not taken into account.

Uncertainty distributions are assumed to be symmetric for Approach 1. For the Monte Carlo simulation, some asymmetric distributions (triangle) were adopted.

For source categories with quantitative uncertainty data available, the input information from studies or from the data suppliers is used for the uncertainty evaluation. This is mainly the case for key categories. For several key categories, no explicit information on uncertainties is available. For these cases, authors of the NIR chapters, FOEN experts involved and several data suppliers derived estimates of uncertainties based on the IPCC 2006 Guidelines (IPCC 2006) default values and on information concerning the process of data collection for activity data and emission factors (import or sales statistics, surveys or modelling). Several experts from data suppliers were contacted for further information on some of the uncertainties. Some industry associations/sources also provided published or unpublished uncertainty estimates for their data. The data sources can be found in the relevant sub-sections on "Uncertainties and Time-Series Consistency" in each of the sectoral chapters (3–9) below.

For categories with no quantitative uncertainty data available, the NIR provides qualitative estimates of uncertainties. The elaboration of a quantitative uncertainty assessment for these categories would present a large effort with only limited effect on the overall uncertainty and therefore it has been decided to realize a semi-quantitative assessment. This includes the definition of a list of the combined uncertainties for all gases and three uncertainty levels: low, medium and high (see Table 1-11). These values are motivated by the comparison of uncertainty analyses of several countries carried out by de Keizer et al. (2007), as presented at the 2nd Internat. Workshop on Uncertainty in Greenhouse Gas Inventories (Vienna 27-28

September 2007), and by Table A1-1 of IPCC Guidelines, Vol. 1, Annex 1, Managing uncertainties (IPCC 1997a).

Table 1-11 Semi-quantitative (combined) uncertainties (U) for the emission of categories with no quantitative uncertainty data available.

Gas	Uncertainty Category	Combined Uncertainty
CO_2	low	2%
	medium	10%
	high	40%
CH_4	low	15%
	medium	30%
	high	60%
N_2O	low	40%
	medium	80%
	high	150%
HFC	medium	20%
PFC	medium	20%
SF_6	medium	20%

Despite the investigation carried out for the current uncertainty analyses it will be necessary to further motivate institutions to supply not only average data but also estimates of associated uncertainties.

1.7.1.3 Results of Approach 1 Uncertainty Evaluation

Level and trend uncertainty analyses are carried out excluding and including the LULUCF sector. Table 1-12 gives a summary for the Approach 1 uncertainties for the national total emissions and removals.

Table 1-12 Switzerland's relative uncertainties for national total GHG emission excluding and including the LULUCF sector – Approach 1: Level uncertainties 2013 and trend uncertainties 1990-2013.

Approach 1 Uncertainty Analysis		
Inventory	**Level uncertainty 2013**	**Trend uncertainty 1990-2013**
excl. LULUCF	3.69%	1.95%
incl. LULUCF	7.08%	2.99%

Main results for the Switzerland's GHG inventory:

- The level uncertainty 2013 is 3.69% excluding LULUCF but 7.08% including LULUCF. Explanations are given below in the section on Approach 2 results.
- The trend uncertainty 1990-2013 is 1.95% excluding LULUCF but 2.99% including LULUCF.

Compared to the results of the previous inventory 2012 (FOEN 2014)

- Level uncertainty 2012 was 3.65% excl. LULUCF but 7.43% incl. LULUCF
- Trend uncertainty 1990-2012 was 1.87% excl. LULUCF but 2.46% incl. LULUCF.

The results of previous and latest analyses look rather similar. Differences are caused by slight modifications of uncertainties for a small number of categories (see sectoral chapters to uncertainties) and caused also by restructuring of source categories due to new Guidelines (IPCC 2006, UNFCCC 2014a).

Detailed results of the Approach 1 uncertainty analysis for GHG emissions 2013 per category are shown in Table A – 2. Details of the uncertainty estimates for specific source categories are provided in the sub-sections on “Uncertainties and Time-Series Consistency” in each of the chapters on source categories below.

It should be noted that the results of the Approach 1 uncertainty analysis for GHG emissions do not, or not fully, take into account the following factors that may further increase uncertainties:

- correlations between source categories that are not considered by Approach 1 (e.g. production data used for industry emissions in both categories 1A2 Manufacturing Industries and 2 Industrial Processes, or cattle numbers used for emissions related to enteric fermentation and animal manure production);
- errors due to the assumption of constant parameters;
- errors due to non-normal, asymmetric distribution of the uncertainties;
- errors due to methodological shortcomings;
- errors due to sources not reported (these are assumed to be very small).

On the other hand, the Approach 2 uncertainty evaluation described below explicitly takes into account correlations between sources and asymmetric distributions.

1.7.1.4 Results of Approach 2 Uncertainty Evaluation (Monte Carlo)

An Approach 2 uncertainty analysis for Switzerland’s GHG Inventory was carried out for the inventory submitted in 2014 (FOEN 2014). For the current inventory year 2015 the Monte Carlo simulation has been updated based on the restructured source and sink categories in line with the updated Guidelines (IPCC 2006, UNFCCC 2014a).

The principle of Monte Carlo analysis is to select random values for emission factor and activity data from within their individual probability distributions, and to calculate the corresponding emission values. This procedure is repeated until an adequately stable result has been found. The results of all iterations yield the overall emission probability distribution.

In the present analysis, Monte Carlo simulations were performed to estimate uncertainties both in emissions 2013 and in emission trends 1990–2013, at the source category level as well as for the inventory as a whole (excluding and including LULUCF). The simulations were run with the commercial software package Crystal Ball (® Decisioneering). This tool generates random numbers within user defined probability ranges and probability distributions. As a result, selected statistics are produced for the forecast variables.

Assumptions for the Monte Carlo simulations are given in Annex 2. In this chapter, only the main results of the simulations for level and trend analyses are presented.

Table 1-13 Switzerland's relative uncertainties for national total GHG emission excluding and including the LULUCF sector – Approach 2: Level uncertainties 2013 and trend uncertainties 1990-2013. (Note that the emission trend 1990-2013 is -1.40% excl. LULUCF and 2.32% incl. LULUCF).

Approach 2 (Monte Carlo) Uncertainty Analysis						
Version	**Level uncertainty 2013**			**Trend uncertainty 1990-2013**		
	2.5 percentile	97.5 percentile	**mean**	2.5 percentile	97.5 percentile	**mean**
excl. LULUCF	-3.22%	3.53%	**3.38%**	-3.81%	1.20%	**2.50%**
incl. LULUCF	-6.71%	6.85%	**6.78%**	-5.51%	10.45%	**7.98%**

Uncertainties excluding LULUCF

- The total uncertainty level of Switzerland's 2013 national total GHG emissions is **3.38%**. The 95% confidence interval is slightly asymmetric and lies between **96.78% and 103.53%.**
- The trend in national total emissions between 1990 and 2013 is –1.40%. With a probability of 95%, the trend lies within the range of **-3.81% to +1.20%**, corresponding to a mean trend uncertainty of **2.50%.**

Uncertainties including LULUCF

- The total uncertainty level of Switzerland's 2013 national total GHG emissions is **6.78%.** The 95% confidence interval is slightly asymmetric and lies between **93.29% and 106.85%**.
- The trend in national total emissions between 1990 and 2013 is 2.32%. With a probability of 95%, the trend lies within the range of **-5.51% to +10.45%,** corresponding to a mean trend uncertainty of **7.98%.**

That means that level and trend uncertainty are much higher if LULUCF categories are included in the uncertainty analysis, which is caused by large contributions, large uncertainties and large trends of several LULUCF categories.

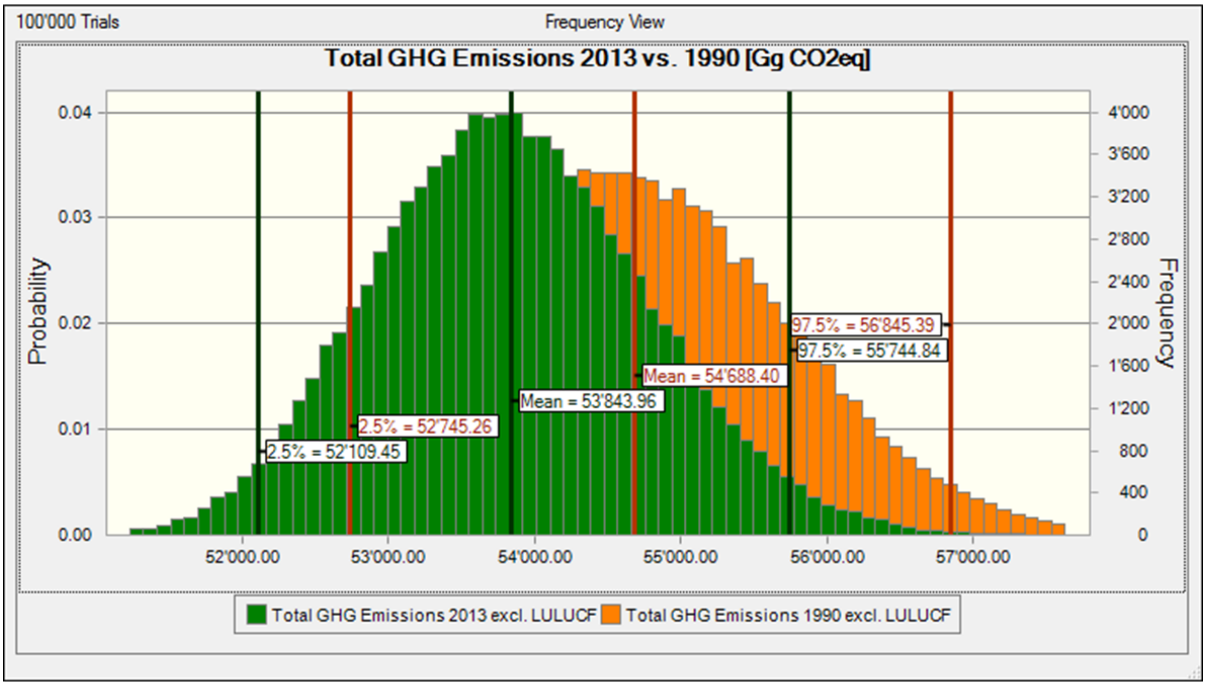


Figure 1-3 Probability distributions of the simulated total emissions excluding LULUCF for the base year 1990 (in orange) and year t=2013 (in green). On the horizontal axis the total emissions (excl. LULUCF) are given in kt CO_2 eq. The number of Monte Carlo runs is 100'000. The vertical lines show simulated mean and percentile values. Note that the simulated values deviate from the reported inventory values (see Table A – 9 for detailed deviations: E.g. the simulated value 2013 is 53'844 kt CO_2 eq, whereas the reported value is 52'561 kt CO_2 eq, 2.4% lower than the simulated value).

The uncertainties are also evaluated by gas with the following results of the Monte Carlo simulation. CO_2 emissions have the highest precision or the lowest uncertainties (1.81%) among the Kyoto gases, as expected.

Table 1-14 Approach 2 level uncertainties by gas 2013 for the total national emissions excluding LULUCF.

Gas	**Emission 2013 (excl. LULUCF** kt CO_2 eq	**Lower bound 2.5 percentile** kt CO_2 eq	**Upper bound 97.5 percentile** kt CO_2 eq	**Mean absolute uncertainty** kt CO_2 eq	**Mean relative uncertainty** %
CO_2	43'173	42'403	43'963	780	1.81%
CH_4	5'148	4'392	5'922	765	14.86%
N_2O	2'415	1'561	3'436	938	38.82%
HFC	1'520	1'289	1'753	232	15.26%
PFC	52	47	57	5	9.28%
SF_6	252	214	291	38	15.22%
NF_3	0.10	0.01	0.18	0.09	92.77%
Total	**52'561**	**50'868**	**54'417**	**1'774**	**3.38%**

Detailed results per category of the Monte Carlo simulation are presented in Table A – 8, inputs on probability distributions and correlation coefficients in Tables A – 3 to A – 7.

The following chart - called Tornado plot - shows the results of a sensitivity analysis, depicting the most important uncertainties. These can either be emission factors, activity data or emissions. The bars depict the amount of uncertainty introduced compared to total emissions (on x-axis). On the left-hand side, the variable is indicated containing the information of type (EM emission, EF emission factor, AD activity data), NFR number and gas. The letter "t" refers to year 2013.

The source category 4C1 Grassland remaining grassland with an uncertainty of 2260% (!) of its CO_2 emission factor contributes most strongly to the level uncertainty. It is followed by the sink category 4A1 Forest land remaining forest land (CO_2), 3Da Direct soil emissions (N_2O) and another LULUCF category 4B1 Cropland remaining cropland. The fact that three out of the four most important contributors stem from the LULUCF sector explains the result given above that the level uncertainty including LULUCF is twice as high as without LULUCF.

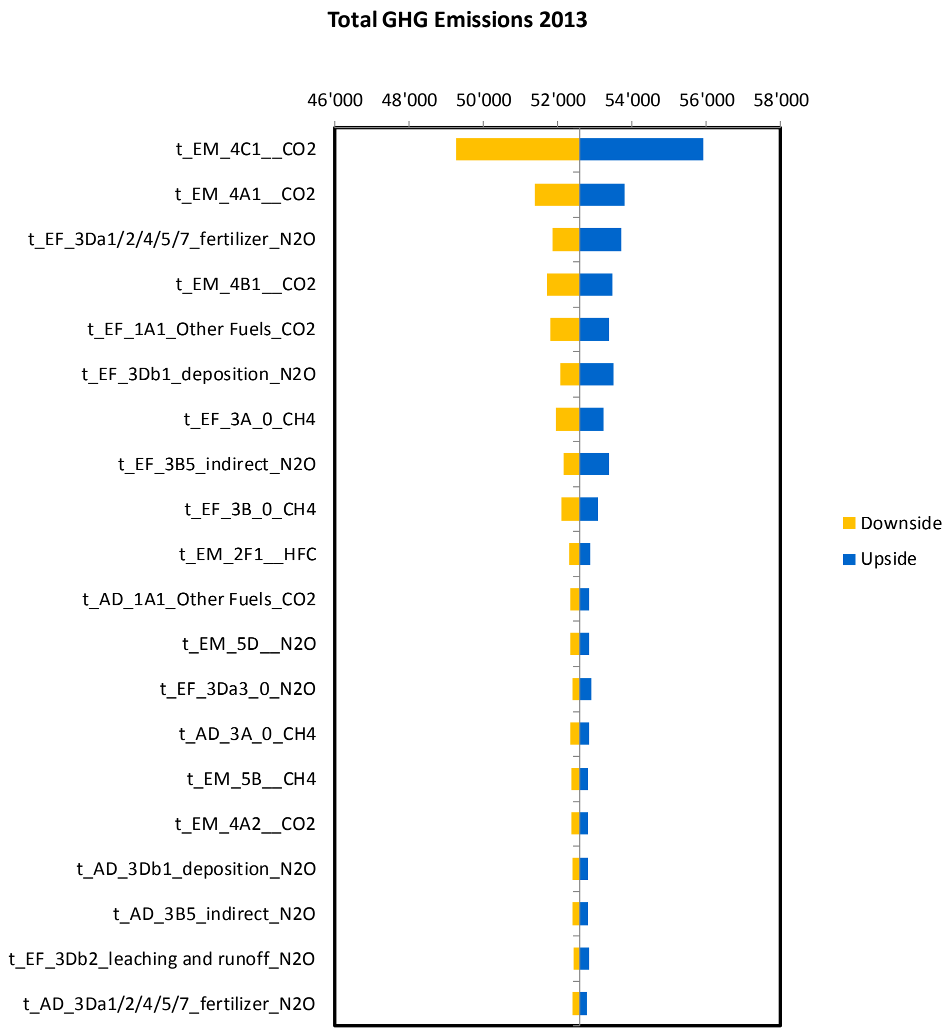


Figure 1-4 Tornado plot of the uncertainties by category. Abbrev.: "t" refers to 2013, "EF" emission factor, "AD" activity data, "EM" emissions. X-axis: Simulated national total of CO_2 eq emissions (in kt) including LULUCF in 2013 (note that the simulated value deviate from the reported inventory values, see Table A – 9 for details). The width of the bar show the combined uncertainty introduced by the corresponding uncertainty.

Further results of the Monte Carlo simulations are shown in Annex 2.2.

1.7.1.5 Comparison of Approach 1 and Approach 2

In the GHG inventory, some of the uncertainties may become large, their statistical distribution may clearly deviate from normal distributions, and they can be correlated. Approach 1 is based on simple error propagation, which assumes only small, normally distributed and uncorrelated uncertainties. The application of the Approach 1 is therefore not the optimal instrument for determining the uncertainties of a GHG inventory. The more appropriate choice, which is recommended by the IPCC 2006 Guidelines (IPCC 2006), is the Monte Carlo simulation (Approach 2), which is designed for uncertainties of any shape, any size of uncertainties, any correlated figures. The results of the Monte Carlo simulation are therefore considered to provide a more realistic picture of the uncertainties than the results of Approach 1.

Level uncertainty

Approach 2 excl. LULUCF produces an overall level uncertainty (3.38%) which is slightly lower than the result of Approach 1 (3.69%). The correct treating of large uncertainties, asymmetric distributions for agricultural sources and the existence of relevant correlations do all together decrease the level uncertainty slightly. The same holds for the level uncertainty incl. LULUCF: Approach 2 produces an overall level uncertainty (6.78%) which is also slightly lower than the result of Approach 1 (7.08%).

Trend uncertainty

For the trend uncertainty Approach 2 produces higher uncertainties than Approach 1. Excl. LULUCF Approach 2 trend uncertainty (2.50%) is not much higher than Approach 1 (1.95%), but there is a large difference if LULUCF is included: Approach 2 trend uncertainty is 7.98%, whereas Approach 1 trend uncertainty is only 2.99%. Positive correlations for activity data and emission factors between the base year and 2013 tend to increase the trend uncertainty. Including LULUCF, this mechanism is enforced due to large uncertainties of several LULUCF categories.

1.7.2 KP-LULUCF Inventory

Uncertainty estimates for KP-LULUCF activities are presented in chapter 11.3.1.5.

2 Trends in Greenhouse Gas Emissions and Removals

This chapter provides an overview of Switzerland's GHG emissions/removals and trends for the period 1990–2013. Numbers in the chapters 2.1-2.4 are relevant for reporting under the UNFCCC, whereas numbers in chapter 2.5 refer to accounting under the KP.

2.1 Aggregated Greenhouse Gas Emissions 2013 (UNFCCC)

In 2013, Switzerland emitted 52'561 kt CO_2 equivalent (excluding LULUCF and international bunkers) to the atmosphere or 6.50 tonnes CO_2 equivalent per capita (inhabitants 2013: 8.089 million, SFSO 2014a). The largest contributing gas was CO_2 (excluding LULUCF and international bunkers) with 43'173 kt (5.34 tonnes per capita), and the most important source was sector 1 Energy, 41'452 kt CO_2 equivalent (Table 2-1). A breakdown of Switzerland's total emissions by gas (excluding LULUCF) is given in Figure 2-1. Figure 2-2 charts the relative contributions of the individual sectors (excluding LULUCF) to the emission of each GHG.

Table 2-1 Switzerland's GHG emissions in CO_2 equivalent (kt) by gas and sector in 2013.

Emissions 2013	**CO_2**	**CH_4**	**N_2O**	**HFCs**	**PFCs**	**SF_6**	**NF_3**	**Total**	**Share**
	CO_2 equivalent (kt)								
1 Energy	40'913	306	233					41'452	78.9%
2 Industrial processes	2'195	2	71	1'520	52	252	0	4'093	7.8%
3 Agriculture	42	3'999	1'909					5'949	11.3%
5 Waste	10	841	202					1'053	2.0%
6 Other sources	13	1	1					14	0.0%
Total (excluding LULUCF and HWP)	43'173	5'148	2'415	1'520	52	252	0	**52'561**	100.0%
4 Land use, land-use change and forestry and harvested wood products	-1'119	11	72					-1'036	-2.0%
Total (including LULUCF and HWP)	42'054	5'159	2'487	1'520	52	252	0	**51'525**	98.0%
International aviation bunkers	4'711	2	45					*4'757*	
International marine bunkers	26	0.01	0.25					*26*	

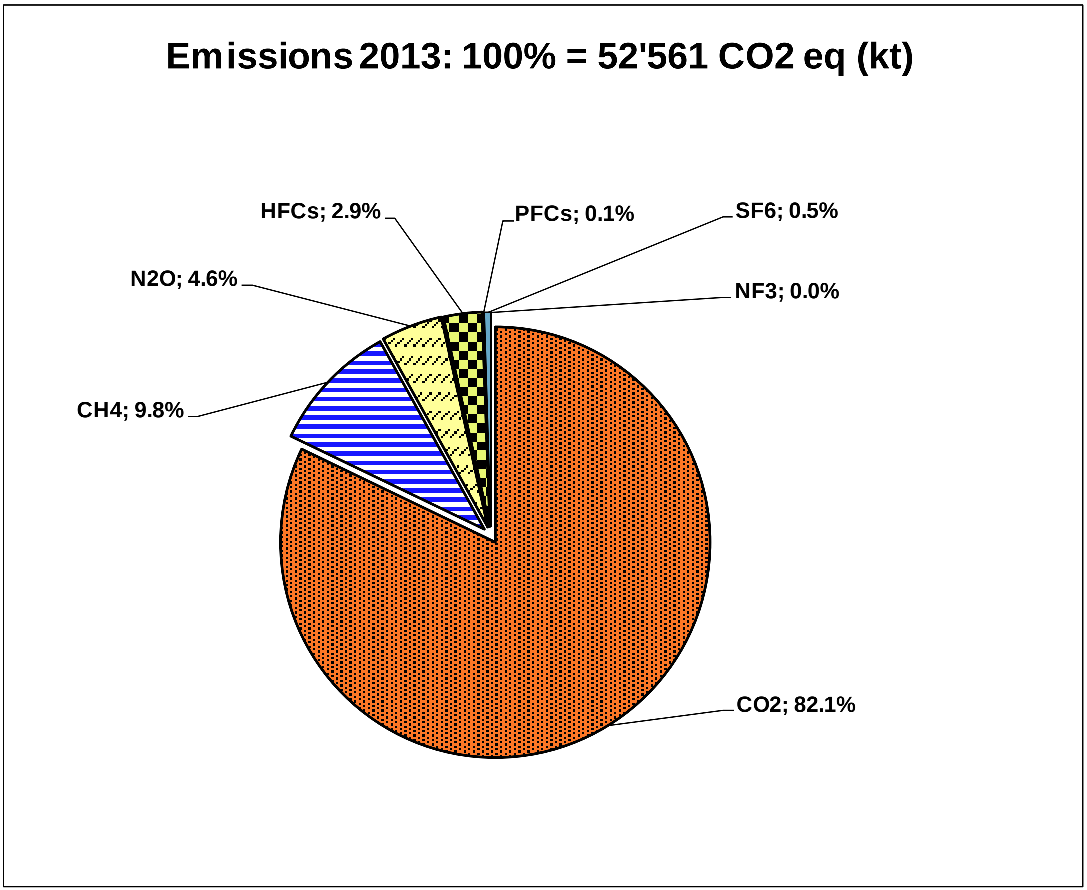


Figure 2-1 Contribution of individual gases to Switzerland's GHG emissions (excluding LULUCF) in 2013. 100% corresponds to 52'561 CO_2 eq (kt).

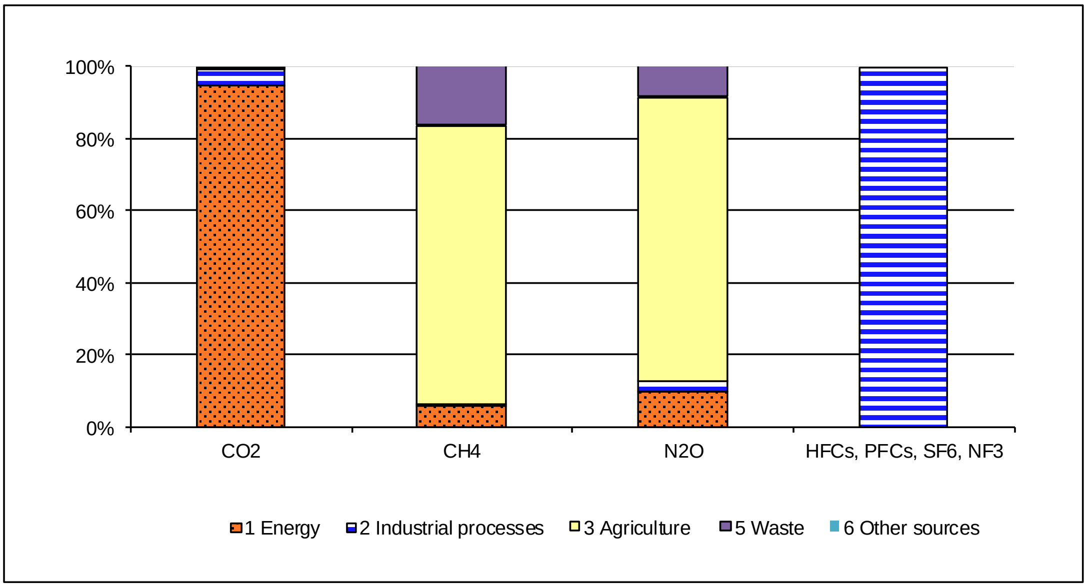


Figure 2-2 Relative contributions of the individual sectors (excluding LULUCF) to GHG emissions in 2013.

Fuel combustion within the energy sector was by far the largest source of emissions of CO_2 in 2013. Emissions of CH_4 and N_2O originated mainly from agriculture, and the F-gas emissions stemmed by definition from industrial processes.

2.2 Emission Trends by Gas

Emission trends by gas for the period 1990–2013 are summarized in Table 2-2.

Table 2-2 Switzerland's GHG emissions in CO_2 equivalent (kt) by gas; 1990–2013. The column below on the far right (digits in italic) indicates the percentage change in emissions in 2013 as compared to the base year 1990. HFCs increased by 6'133'179% when compared to 1990 levels (0.025 kt CO_2 equivalent).

Greenhouse Gas Emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	CO_2 equivalent (kt)									
CO2 emissions including net CO2 from LULUCF and HWP	40'956	43'213	43'095	39'641	39'720	39'658	41'017	39'562	41'396	42'008
CO_2 emissions excluding net CO_2 from LULUCF and HWP	44'031	46'101	45'973	43'556	42'593	43'352	44'088	42'980	44'540	44'364
CH_4 emissions including CH_4 from LULUCF	6'205	6'200	6'084	5'958	5'903	5'885	5'811	5'694	5'585	5'474
CH_4 emissions excluding CH_4 from LULUCF	6'169	6'186	6'072	5'946	5'885	5'864	5'795	5'649	5'569	5'463
N_2O emissions including N_2O from LULUCF	2'941	2'930	2'897	2'830	2'800	2'786	2'780	2'689	2'678	2'640
N_2O emissions excluding N_2O from LULUCF	2'854	2'848	2'816	2'748	2'717	2'702	2'697	2'602	2'597	2'560
HFCs	0	2	16	33	82	246	297	361	456	530
PFCs	117	99	81	35	21	17	20	21	24	26
SF_6	137	139	141	121	107	93	90	124	153	140
NF_3	0	0	0	0	0	0	0	0	0	0
Total (including LULUCF and HWP)	**50'355**	**52'582**	**52'314**	**48'617**	**48'632**	**48'686**	**50'015**	**48'452**	**50'292**	**50'818**
Total (excluding LULUCF and HWP)	**53'308**	**55'374**	**55'098**	**52'438**	**51'405**	**52'276**	**52'988**	**51'737**	**53'338**	**53'082**

Greenhouse Gas Emissions	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	CO2 equivalent (kt)									
CO2 emissions including net CO2 from LULUCF and HWP	42'974	45'943	44'137	42'930	42'052	43'276	43'668	41'124	43'163	41'688
CO_2 emissions excluding net CO_2 from LULUCF and HWP	43'503	44'979	43'366	44'574	45'137	45'731	45'343	43'341	44'658	43'525
CH_4 emissions including CH_4 from LULUCF	5'382	5'370	5'309	5'200	5'139	5'150	5'186	5'209	5'289	5'201
CH_4 emissions excluding CH_4 from LULUCF	5'371	5'358	5'288	5'177	5'128	5'138	5'173	5'193	5'277	5'189
N_2O emissions including N_2O from LULUCF	2'635	2'650	2'628	2'579	2'535	2'532	2'531	2'554	2'573	2'535
N_2O emissions excluding N_2O from LULUCF	2'555	2'571	2'547	2'498	2'457	2'449	2'449	2'474	2'497	2'461
HFCs	625	723	802	897	1'020	1'071	1'118	1'194	1'245	1'253
PFCs	50	28	33	62	65	44	52	49	58	63
SF_6	144	145	158	165	186	203	186	172	222	180
NF_3	0	0	0	0	0	0	0	0	0	5
Total (including LULUCF and HWP)	**51'810**	**54'859**	**53'066**	**51'833**	**50'998**	**52'276**	**52'740**	**50'302**	**52'550**	**50'925**
Total (excluding LULUCF and HWP)	**52'247**	**53'803**	**52'194**	**53'373**	**53'993**	**54'635**	**54'319**	**52'423**	**53'957**	**52'676**

Greenhouse Gas Emissions	2010	2011	2012	2013	Change baseyear to 2013 (%)
	CO2 equivalent (kt)				
CO2 emissions including net CO2 from LULUCF and HWP	42'961	38'210	40'427	42'054	2.7%
CO_2 emissions excluding net CO_2 from LULUCF and HWP	45'050	40'983	42'242	43'173	-1.9%
CH_4 emissions including CH_4 from LULUCF	5'207	5'167	5'163	5'159	-16.9%
CH_4 emissions excluding CH_4 from LULUCF	5'196	5'152	5'151	5'148	-16.6%
N_2O emissions including N_2O from LULUCF	2'583	2'533	2'527	2'487	-15.4%
N_2O emissions excluding N_2O from LULUCF	2'509	2'460	2'454	2'415	-15.4%
HFCs	1'335	1'415	1'495	1'520	see caption
PFCs	64.57	67.76	71.31	52.01	-55.4%
SF_6	147.97	159.53	208.91	252.46	84.3%
NF_3	8.48	6.24	0.36	0.10	-
Total (including LULUCF and HWP)	**52'307**	**47'559**	**49'892**	**51'525**	**2.3%**
Total (excluding LULUCF and HWP)	**54'311**	**50'244**	**51'623**	**52'561**	**-1.4%**

The emission trends for individual gases are as follows (see Table 2-2 above, Table 2-3 and Figure 2-3 below):

- Total emissions (excluding LULUCF) show a minimum of 93.0% in 2011 and a maximum of 107.6% in 2001 (100%: value of base year 1990). In 2013, the total emissions excluding LULUCF were 1.4% below the emissions recorded in the base year 1990. CO_2 contributed the largest share of emissions in 2013, accounting for 82.1% of the total in 2013.
- Total emissions (including LULUCF) in 2013 show an increase of 2.3% compared to the emissions recorded in the base year 1990. The net CO_2 emissions/removals from LULUCF show considerable variability from year to year, because heavy storms in 1990 and 1999 ("Lothar") and other factors influence the wood harvesting and tree mortality rates in forests. In the period 1990-2013, wood harvesting generally increased but is still

exceeded by the growth of living biomass. This led to reductions in net removals within the LULUCF sector between 1990 and 2013. Within the first commitment period 2008-2012, the total net CO_2 sink steadily increased (except 2012).

- A comparison of CO_2 emissions with the number of heating degree days in the period 1990–2013 (see Figure 2-7 below) indicates a strong correlation between CO_2 emissions and winter climatic conditions. However in the last few years, an increase in heating degree days did not proportionally translate into an equal increase in CO_2 emissions. For a definition of heating degree days see footnote 1 displayed with Figure 2-7.
- Between 1990 and 2013, CH_4 (excluding LULUCF) decreased by 16.6%, which was mainly attributable to a reduction of livestock that led to a reduction of emissions from enteric fermentation. Moreover, from 2000, a change in waste legislation, banning the disposal of municipal solid waste in landfills, contributed to this trend. The CH_4 share of total GHG emissions decreased from 12.0% in 1990 to 9.8% in 2013.

  In parallel to the reduction of CH_4 due to decreases in livestock populations, N_2O emissions from manure management and agricultural soils declined. Total N_2O emissions (excluding LULUCF) dropped by 15.4% between 1990 and 2013 and accounts now for 4.6% of total emissions.
- HFC emissions increased significantly due to their application as substitutes for CFCs, while PFC emissions declined by 55.4%. SF_6 emissions have shown relatively large fluctuations between 90.1 and 252.5 kt CO_2 eq since 1990. In 2013, SF_6 emissions increased by 84.3% compared to 1990. The share of all F-gases (HFCs, PFCs, SF_6 and NF_3) in total emissions (excluding LULUCF) increased from 0.5% in 1990 to 3.5% in 2013.

Table 2-3 Switzerland's total GHG emissions (excluding LULUCF) in CO_2 equivalent (kt), selected years.

Greenhouse Gas Emissions	**1990**		**1995**		**2000**		**2005**	
(excluding LULUCF and HWP)	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%
CO_2	44'031	82.6%	43'352	82.9%	43'503	83.3%	45'731	83.7%
CH_4	6'169	11.6%	5'864	11.2%	5'371	10.3%	5'138	9.4%
N_2O	2'854	5.4%	2'702	5.2%	2'555	4.9%	2'449	4.5%
HFCs	0	0.0%	246	0.5%	625	1.2%	1'071	2.0%
PFCs	117	0.2%	17	0.0%	50	0.1%	44	0.1%
SF_6	137	0.3%	93	0.2%	144	0.3%	203	0.4%
NF_3	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total (excluding LULUCF and HWP)	**53'308**	**100%**	**52'276**	**100%**	**52'247**	**100%**	**54'635**	**100%**

Greenhouse Gas Emissions	**2010**		**2011**		**2012**		**2013**	
(excluding LULUCF and HWP)	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%
CO_2	45'050	82.9%	40'983	81.6%	42'242	81.8%	43'173	82.1%
CH_4	5'196	9.6%	5'152	10.3%	5'151	10.0%	5'148	9.8%
N_2O	2'509	4.6%	2'460	4.9%	2'454	4.8%	2'415	4.6%
HFCs	1'335	2.5%	1'415	2.8%	1'495	2.9%	1'520	2.9%
PFCs	65	0.1%	68	0.1%	71	0.1%	52	0.1%
SF_6	148	0.3%	160	0.3%	209	0.4%	252	0.5%
NF_3	8	0.0%	6	0.0%	0	0.0%	0	0.0%
Total (excluding LULUCF and HWP)	**54'311**	**100%**	**50'244**	**100%**	**51'623**	**100%**	**52'561**	**100%**

Figure 2-3 shows Switzerland's relative GHG emission trends by gas. The base year 1990 is set to 100%.

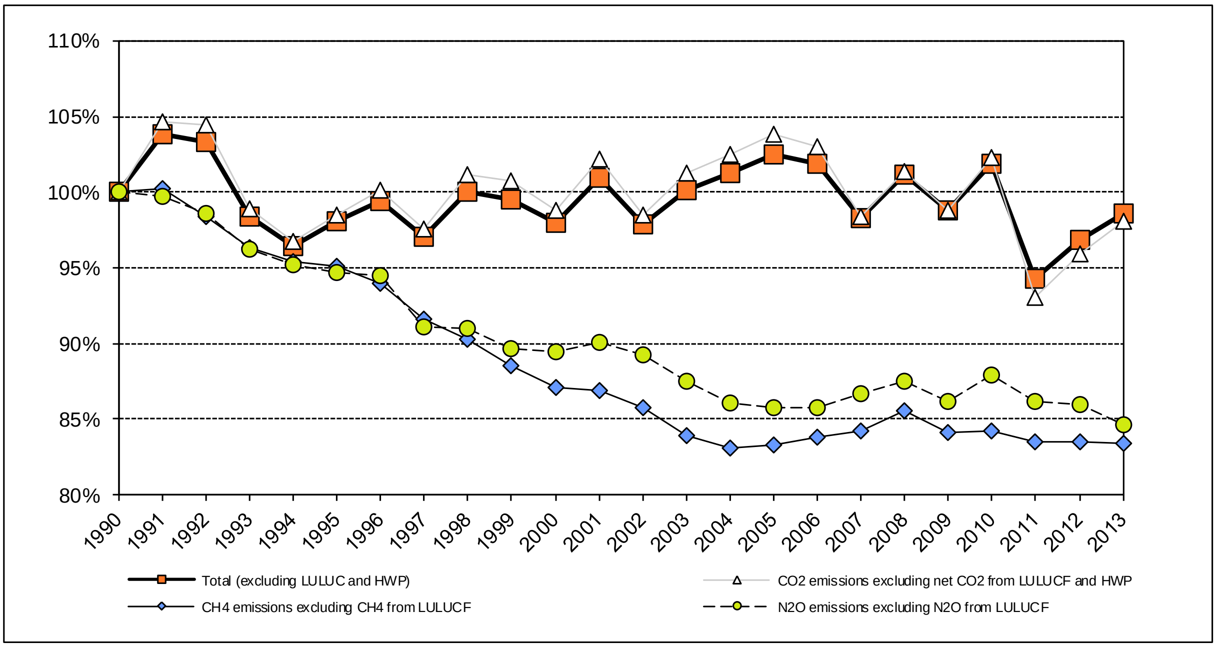


Figure 2-3 Relative trend of Switzerland's GHG emissions excluding LULUCF by gas, 1990–2013 (base year 1990: 100%). The increase of the F-gases is not shown (620% in 2013, compared to 1990).

2.3 Emission Trends by Sources and Sinks

Table 2-4 shows the emission trends for all major sources and sink categories. As the largest share of emissions originated from the energy sector, the table also includes the contributions of the energy sub-sectors.

Table 2-4 Switzerland's GHG emissions in CO_2 equivalent (kt) by sources and sinks, 1990–2013. The column below on the far right (digits in italic) indicates the percentage change in emissions in 2013 as compared to the base year 1990.

Source and Sink Categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	CO_2 equivalent (kt)									
1. Energy	41'707	44'177	44'207	42'026	40'890	41'803	42'717	41'749	43'298	43'093
1A1 Energy industries	2'558	2'851	2'946	2'617	2'661	2'698	2'917	2'912	3'273	3'298
1A2 Manufacturing industries and construction	6'260	6'562	6'138	5'967	5'896	6'069	5'872	5'798	5'995	5'857
1A3 Transport	14'613	15'105	15'428	14'359	14'545	14'229	14'290	14'847	15'058	15'667
1A4 Other sectors	17'666	19'021	19'052	18'439	17'159	18'200	19'042	17'603	18'408	17'746
1A5 Other	206	188	180	171	166	148	137	147	146	132
1B Fugitive emissions from fuels	405	449	463	472	464	459	458	441	419	394
2. Industrial processes	3'522	3'157	2'997	2'691	2'881	2'873	2'749	2'666	2'782	2'845
3. Agriculture	6'713	6'674	6'557	6'456	6'440	6'413	6'367	6'182	6'141	6'055
5. Waste	1'355	1'354	1'324	1'253	1'181	1'173	1'142	1'126	1'103	1'076
6. Other sources	12	12	13	13	13	13	13	14	14	14
Total (excluding LULUCF and HWP)	53'308	55'374	55'098	52'438	51'405	52'276	52'988	51'737	53'338	53'082
4. Land use, land-use change and forestry and harvested wood products	-2'953	-2'792	-2'784	-3'821	-2'773	-3'590	-2'973	-3'285	-3'046	-2'264
Total (including LULUCF and HWP)	50'355	52'582	52'314	48'617	48'632	48'686	50'015	48'452	50'292	50'818

Source and Sink Categories	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	CO_2 equivalent (kt)									
1. Energy	42'061	43'489	41'892	43'109	43'457	43'918	43'567	41'526	42'886	41'815
1A1 Energy industries	3'216	3'358	3'434	3'427	3'712	3'840	4'056	3'739	3'850	3'696
1A2 Manufacturing industries and construction	5'775	6'040	5'594	5'709	5'841	5'885	6'072	5'879	5'904	5'607
1A3 Transport	15'900	15'602	15'528	15'697	15'777	15'838	15'952	16'273	16'640	16'443
1A4 Other sectors	16'660	17'993	16'851	17'822	17'691	17'923	17'053	15'226	16'090	15'674
1A5 Other	136	134	140	125	114	123	127	120	115	116
1B Fugitive emissions from fuels	373	361	344	328	322	308	306	288	287	278
2. Industrial processes	3'098	3'198	3'235	3'327	3'621	3'775	3'757	3'823	3'904	3'796
3. Agriculture	6'029	6'089	6'054	5'976	5'954	5'993	6'022	6'076	6'180	6'091
5. Waste	1'046	1'013	999	947	948	935	960	984	974	959
6. Other sources	14	14	14	14	14	14	14	14	14	14
Total (excluding LULUCF and HWP)	52'247	53'803	52'194	53'373	53'993	54'635	54'319	52'423	53'957	52'676
4. Land use, land-use change and forestry and harvested wood products	-437	1'055	872	-1'540	-2'995	-2'359	-1'579	-2'121	-1'407	-1'751
Total (including LULUCF and HWP)	51'810	54'859	53'066	51'833	50'998	52'276	52'740	50'302	52'550	50'925

Source and Sink Categories	2010	2011	2012	2013	2013/1990
	CO_2 equivalent (kt)				%
1. Energy	43'192	39'145	40'525	41'452	*-0.6%*
1A1 Energy industries	3'873	3'620	3'653	3'678	*43.8%*
1A2 Manufacturing industries and construction	5'718	5'271	5'267	5'377	*-14.1%*
1A3 Transport	16'340	16'224	16'352	16'245	*11.2%*
1A4 Other sectors	16'856	13'645	14'886	15'768	*-10.7%*
1A5 Other	121	108	116	117	*-43.2%*
1B Fugitive emissions from fuels	283	276	251	267	*-34.1%*
2. Industrial processes	4'017	4'051	4'056	4'093	*16.2%*
3. Agriculture	6'108	6'052	6'015	5'949	*-11.4%*
5. Waste	981	983	1'013	1'053	*-22.3%*
6. Other sources	14	14	14	14	*16.1%*
Total (excluding LULUCF and HWP)	54'311	50'244	51'623	52'561	*-1.4%*
4. Land use, land-use change and forestry and harvested wood products	-2'005	-2'685	-1'731	-1'036	*-64.9%*
Total (including LULUCF and HWP)	52'307	47'559	49'892	51'525	*2.3%*

The percentage shares of source categories are shown for selected years in Table 2-5, Figure 2-4 to Figure 2-6 are graphical representations of Table 2-4 data. For the time series of the sub-sectors of 1 Energy see Chapter 3.

Table 2-5 Switzerland's total gross GHG emissions (excluding LULUCF) in CO_2 equivalent (kt) and the contribution of individual source categories for selected years.

Source and Sink Categories	1990		1995		2000		2005	
	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%
1. Energy	41'707	82.8%	41'803	85.9%	42'061	81.2%	43'918	84.0%
1A1 Energy industries	*2'558*	*5.1%*	2'698	*5.5%*	3'216	*6.2%*	3'840	*7.3%*
1A2 Manufacturing industries and construction	*6'260*	*12.4%*	6'069	*12.5%*	5'775	*11.1%*	5'885	*11.3%*
1A3 Transport	*14'613*	*29.0%*	14'229	*29.2%*	15'900	*30.7%*	15'838	*30.3%*
1A4 Other sectors	*17'666*	*35.1%*	18'200	*37.4%*	16'660	*32.2%*	17'923	*34.3%*
1A5 Other	*206*	*0.4%*	148	*0.3%*	136	*0.3%*	123	*0.2%*
1B Fugitive emissions from fuels	*405*	*0.8%*	459	*0.9%*	373	*0.7%*	308	*0.6%*
2. Industrial processes	3'522	7.0%	2'873	5.9%	3'098	6.0%	3'775	7.2%
3. Agriculture	6'713	13.3%	6'413	13.2%	6'029	11.6%	5'993	11.5%
4. Land use, land-use change and forestry and harvested wood products	-2'953	-5.9%	-3'590	-7.4%	-437	-0.8%	-2'359	-4.5%
5. Waste	1'355	2.7%	1'173	2.4%	1'046	2.0%	935	1.8%
6. Other sources	12	0.0%	13	0.0%	14	0.0%	14	0.0%
Total (including LULUCF and HWP)	50'355	100.0%	48'686	100.0%	51'810	100.0%	52'276	100.0%

Source and Sink Categories	2010		2011		2012		2013	
	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%
1. Energy	43'192	82.6%	39'145	82.3%	40'525	81.2%	41'452	80.5%
1A1 Energy industries	3'873	7.4%	3'620	*7.6%*	3'653	7.3%	3'678	*7.1%*
1A2 Manufacturing industries and construction	5'718	*10.9%*	5'271	*11.1%*	5'267	*10.6%*	5'377	*10.4%*
1A3 Transport	16'340	31.2%	16'224	*34.1%*	16'352	32.8%	16'245	*31.5%*
1A4 Other sectors	16'856	32.2%	13'645	*28.7%*	14'886	*29.8%*	15'768	*30.6%*
1A5 Other	121	*0.2%*	108	*0.2%*	116	*0.2%*	117	*0.2%*
1B Fugitive emissions from fuels	283	*0.5%*	276	*0.6%*	251	*0.5%*	267	*0.5%*
2. Industrial processes	4'017	7.7%	4'051	8.5%	4'056	8.1%	4'093	7.9%
3. Agriculture	6'108	11.7%	6'052	12.7%	6'015	12.1%	5'949	11.5%
4. Land use, land-use change and forestry and harvested wood products	-2'005	-3.8%	-2'685	-5.6%	-1'731	-3.5%	-1'036	-2.0%
5. Waste	981	1.9%	983	2.1%	1'013	2.0%	1'053	2.0%
6. Other sources	14	0.0%	14	0.0%	14	0.0%	14	0.0%
Total (including LULUCF and HWP)	52'307	100.0%	47'559	100.0%	49'892	100.0%	51'525	100.0%

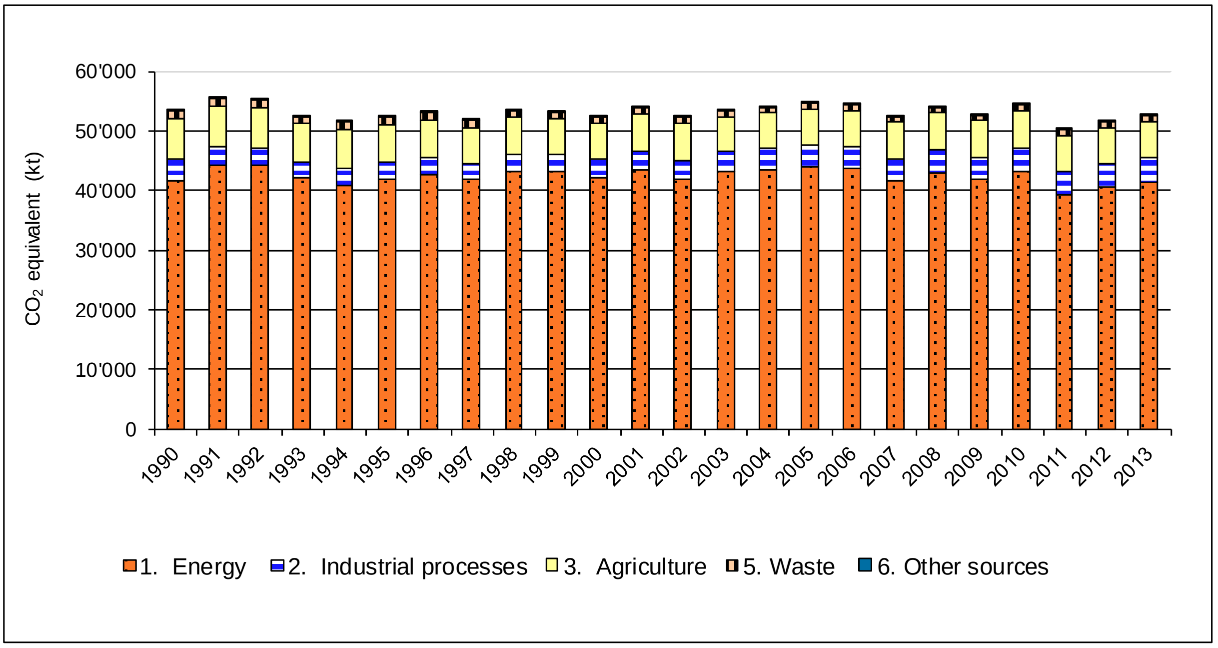


Figure 2-4 Switzerland's GHG emissions in CO_2 equivalent (kt) by sectors, 1990–2013 (excluding LULUCF).

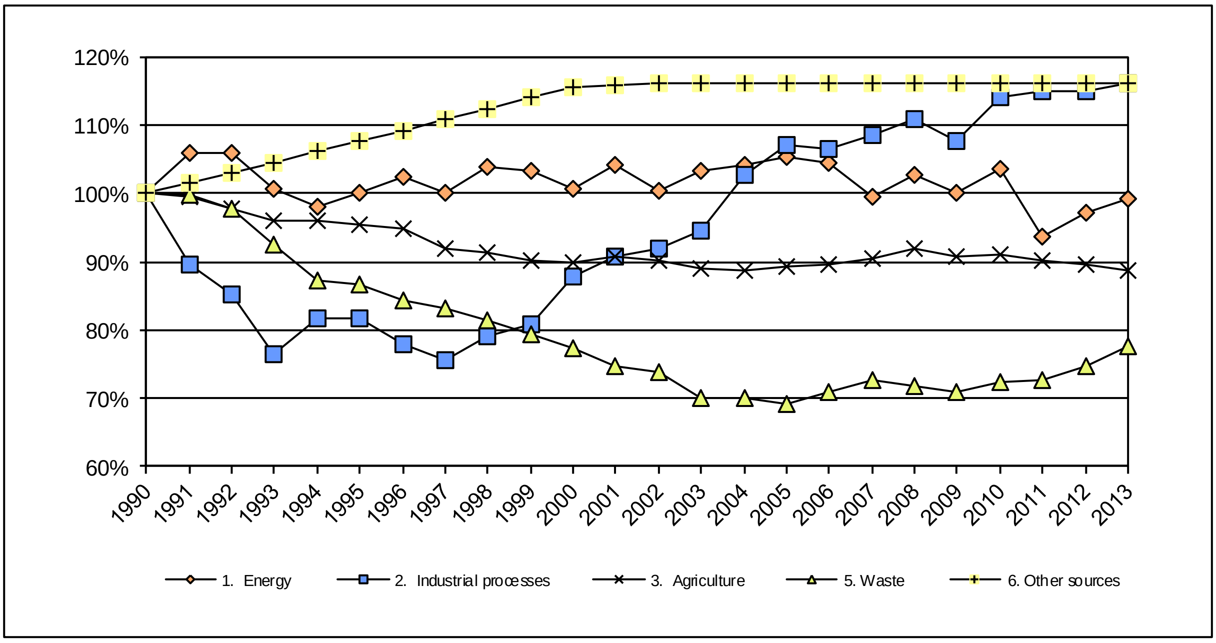


Figure 2-5 Relative emission (CO_2 eq.) trends by main source categories (base year 1990 = 100%).

Emission trends for the various sectors are as follows:

- 1 Energy: the variations can only be understood if the trends within individual source categories are considered separately. See Figure 2-6 and comments below.
- 2 Industrial processes and product use: in line with economic development, overall emissions in the industry sector showed a decreasing trend in the early 90s and a gradual increase between 1998 and 2013, except for the economically difficult year 2009. Since 2005 the Ordinance on Chemical Risk Reduction (Swiss Confederation 2005) is in place and regulates the use of F-Gases, which led to emission stabilization in this source category. 2 A Mineral industry is the dominant source category of sector 2 with a share of 47.8% of the greenhouse gas emissions in 2013 although it decreased by 29% since 1990. Cement production is the most relevant source in this category. Emissions of 2F Product uses as substitutes for ODS, the second most important source in sector 2 increased by more than three orders of magnitude since 1990 due to a replacement of CFCs by HFCs. Source category 2G Other product manufacture and use with SF_6 and PFC emissions from electrical equipment and other product use, as well as N_2O emissions from the application in households and hospitals accounts for 9.4% of the greenhouse gas emissions in sector 2 in 2013 and has increased by 54% since 1990. Other source categories in sector 2 are of minor importance with regard to the overall greenhouse gas emissions.
- 3 Agriculture: declining populations of cattle and swine and reduced fertilizer use have led to a decrease in CO_2 equivalent emissions until 2004. Subsequently emissions increased until 2008 and decreased again afterwards until reaching 88.6% of the 1990 value.
- 5 Waste: Total emissions from the source category waste decreased throughout the period 1990-2013. By a change of legislation in 2000, disposal of combustible wastes in landfills has been banned, leading to an increasing amount of municipal solid waste being incinerated, with emissions reported under source 1A1 Energy industries rather than sector 5 Waste. This leads to a decrease of CH_4 emissions from Sector 5A Solid waste disposal. Simultaneously, CH_4 and N_2O emissions from Sector 5B Biological treatment of solid waste have been increasing since 1990 by a factor of almost 6. Both

effects together lead to a decrease of the emissions between 1990 and 2003 and to slight increase from 2004 to 2014. Altogether, "waste-related" emissions incl. emissions from waste management activities reported in sources 1A1 Energy industries (waste-to-energy), 1A2 Manufacturing industries and construction, 3D Agricultural soils (waste used as fertilizer) and 5 Waste have increased since 1990 by 20% (see Figure 7-3 in Chapter 7.1).

- 6 Other: The total emissions from sector 6 Other increased throughout the period 1990-2000. Since 2000 the emissions are stable. Please consider that emissions from sector 6 Other are not accounted for in the Kyoto Protocol and are only of minor importance (0.03% of total CO_2 equivalent emissions).

The main source categories within the Energy sector – representing the major sources of Switzerland's GHG emissions – are shown in Figure 2-6.

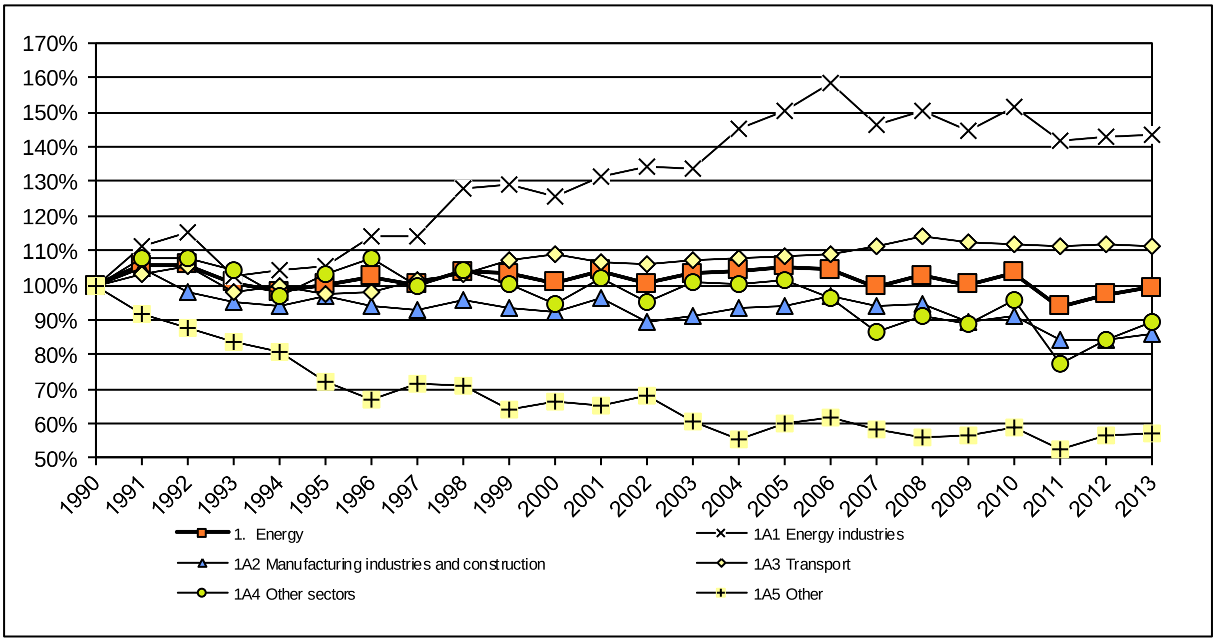


Figure 2-6 Emission trends (CO_2 eq.) for the source categories in sector 1 Energy/1A Fuel combustion. The trend for the entire sector "1 Energy" is shown as orange/bold line. Not included in the figure is the trend for 1B Fugitive emissions, which continuously decreased from 100% in 1990 to 65.9% in 2013.

It is noteworthy that, due to Switzerland's electricity production structure (about 94.3% generated by hydroelectric and nuclear power plants in 2013; see SFOE 2014: Table 24), sector 1A1 Energy industries plays only a minor role – representing not classical thermal power stations but waste incineration plants in the Swiss GHG inventory. The following emission trends emerge within the Energy sector:

- Despite differing trends of individual source categories, the overall emissions from the energy sector remain at relatively constant level (orange/bold line in Figure 2-6) until 2010 but noticeably decreased in 2011, mainly due to an exceptionally warm winter (see Figure 2-7). In 2013 a slight increase was detectable again.
- Overall emissions from source category 1A1 Energy industry 2013 have increased by 43.8% since 1990. Fluctuations are caused by varying combustion activities in the petroleum refinery industry, waste incineration, new installations of district heating and weather related forcing of heating activities (see Figure 2-7). From 2010 to 2011,

emissions from gaseous fuel consumption within source category 1A decreased by 11.3% due to the fact that 2011 was the warmest year measured since measurements started. Note that only 8.9% of sector 1 Energy emissions stem from 1A1.

- The trend for sub-sector 1A3 Transport shows a slight increase over the period 1990–2008 by about 13.9%, but with fluctuations indicating a fairly strong correlation between this sector and overall economic development in Switzerland, with periods of stagnation (1992-1995, 2001–2002) and growth (gross value-added) in 1996–2000 and 2003–2008 (SFSO 2009a, SECO 2015). Since 2008 transport emissions show a slight decrease which points to a relative decoupling from overall economic development.
- The trend for sub-sector 1A4 Other sectors reflects the impact of climatic variations on demand for heating. The strong correlation with the number of "heating degree days"[1] – used as an index of cold weather conditions – is apparent from Figure 2-7, which shows CO_2 emissions from sub-sector 1A4 Fuel combustion – Other sectors (only stationary sources) and the number of heating degree days. In 2013 heating degree days increased by 5.8% compared to 2012 and CO_2 emissions from fuel combustions in source category 1A4 Other sectors – stationary sources increased simultaneously by 6.2%. In the period 1990–2013, the number of buildings and apartments increased, as well as the average floor space per person and workplace. Both phenomena resulted in an increase in the total area heated by more than 30%. Over the same period, however, higher standards were specified for insulation and for combustion equipment efficiency for both new and renovated buildings, compensating for the emissions from the additional area heated.

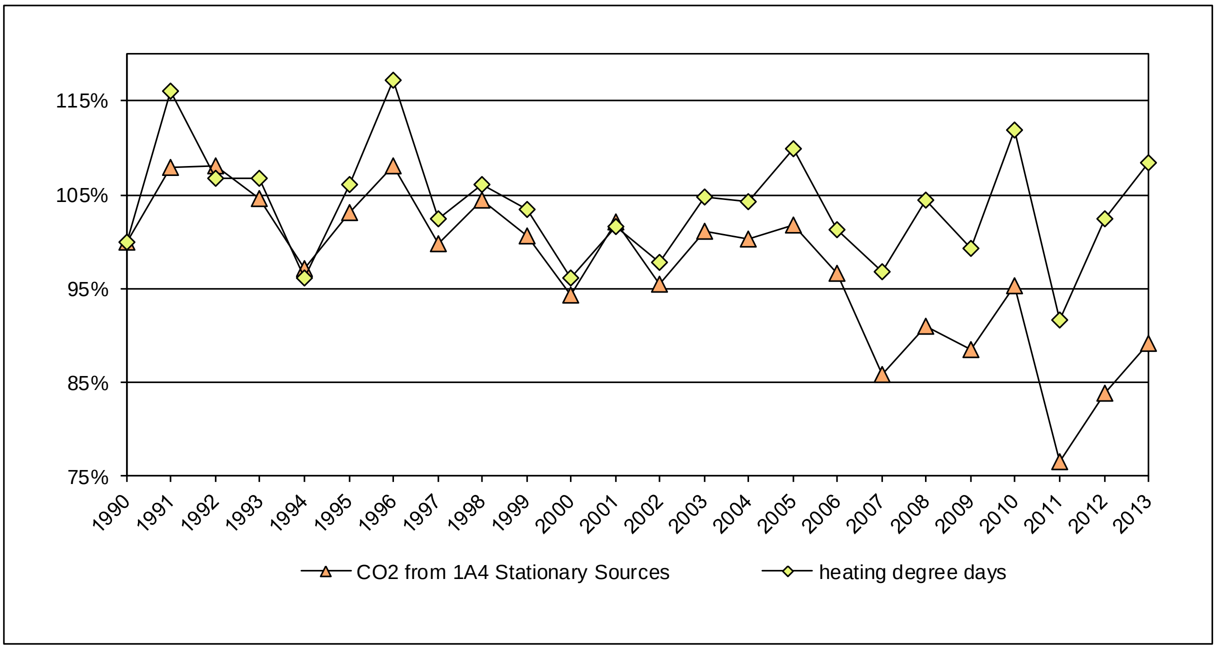


Figure 2-7 Relative trend for CO_2 emissions from 1A4 Fuel Combustion - Other Sectors (stationary sources only) compared with the number of heating degree days.

[1] Heating degree days: Number of degrees per day calculated as the difference between 20°C (room temperature) and the daily average outdoor temperature for such days where the daily average temperature is below 12°C (e.g. daily outdoor average equals 7°C, then for that day 20 – 7 = 13). The number of degrees per day are summed up for a year t to yield the heating degree days of year t.

Figure 2-8 shows the net emissions and removals of sector LULUCF (which includes HWP) in Switzerland. They are dominated by biomass dynamics in forests. Except for 2001 and 2002 the removals in the LULUCF sector were higher than the emissions throughout the period 1990-2013. However, a strong year to year variation is evident over the whole period. The net removals decreased by 64.9% since 1990.The reason for the positive value in 2001 and 2002 is the winter storm “Lothar” end of 1999 which caused great damages in the forest stands and increased harvesting. Note that the annual contributions of CH_4 and N_2O emissions from LULUCF in this period are relatively small (average 96 kt CO_2 equivalent yr^{-1}) compared to the CO_2 emissions and removals.

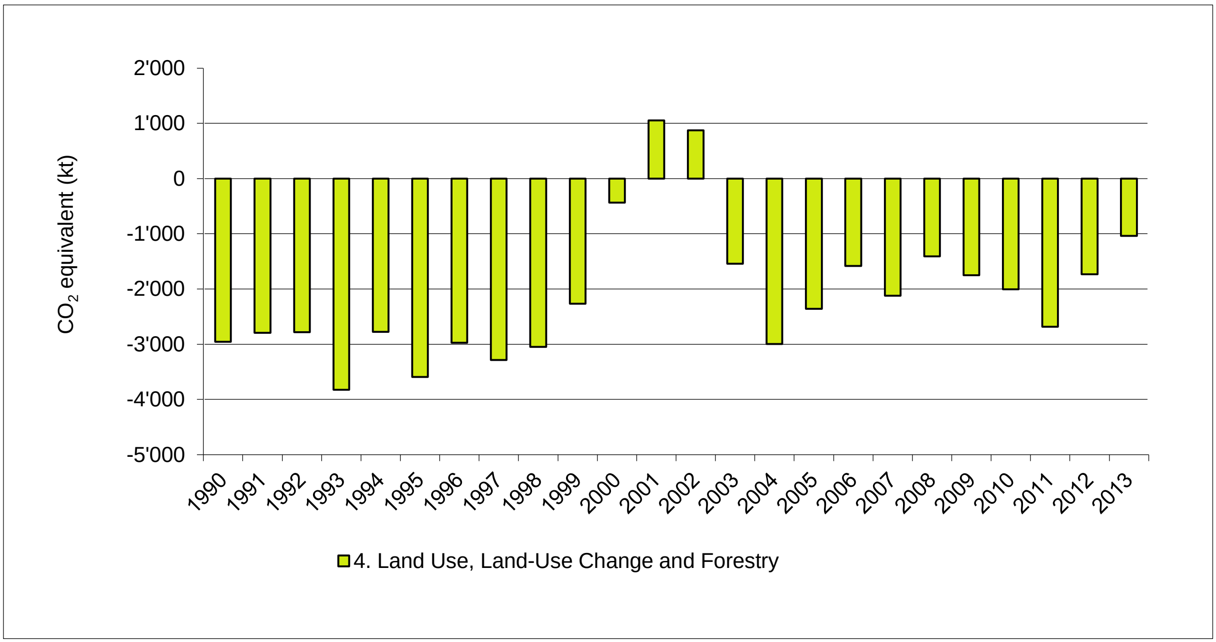


Figure 2-8 Switzerland’s net GHG emissions and removals of sector Land use, land-use change and forestry (LULUCF), 1990–2013 (in kt CO_2 eq). Positive values refer to emissions, negative values refer to removals.

2.4 Emission Trends for Indirect Greenhouse Gases and SO_2

Emission trends for indirect greenhouse gases show a very pronounced decline (see Table 2-6 and Figure 2-9). A strict air pollution control policy and the implementation of a large number of emission reduction measures led to a decrease between 51% and 75% in emissions of respective air pollutants over the period 1990-2013. The main reduction measures were abatement of exhaust emissions from road vehicles and stationary combustion equipment, taxation of solvents and sulphured fuels, and voluntary agreements with industry sectors (FOEN 2010i, Swiss Confederation 1985, 1997).

Table 2-6 Switzerland's indirect GHG and SO_2 emissions (kt), 1990–2013 (without NMVOC from LULUCF).

Indirect Greenhouse Gases and SO_2	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
NO_x	143	141	135	123	122	118	114	110	110	109
CO	800	766	713	628	577	536	516	487	466	453
NMVOC	302	284	264	236	216	199	187	174	161	152
SO_2	40	37	33	27	28	26	26	24	23	17
Indirect Greenhouse Gases and SO_2	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
	kt									
NO_x	107	103	97	95	93	92	89	86	84	78
CO	426	405	377	365	347	330	306	288	278	262
NMVOC	143	135	124	116	106	102	98	95	94	91
SO_2	15	18	15	15	15	16	15	13	13	11
Indirect Greenhouse Gases and SO_2	**2010**	**2011**	**2012**	**2013**						
	kt									
NO_x	76	72	72	71						
CO	251	230	223	216						
NMVOC	90	87	85	84						
SO_2	12	10	10	10						

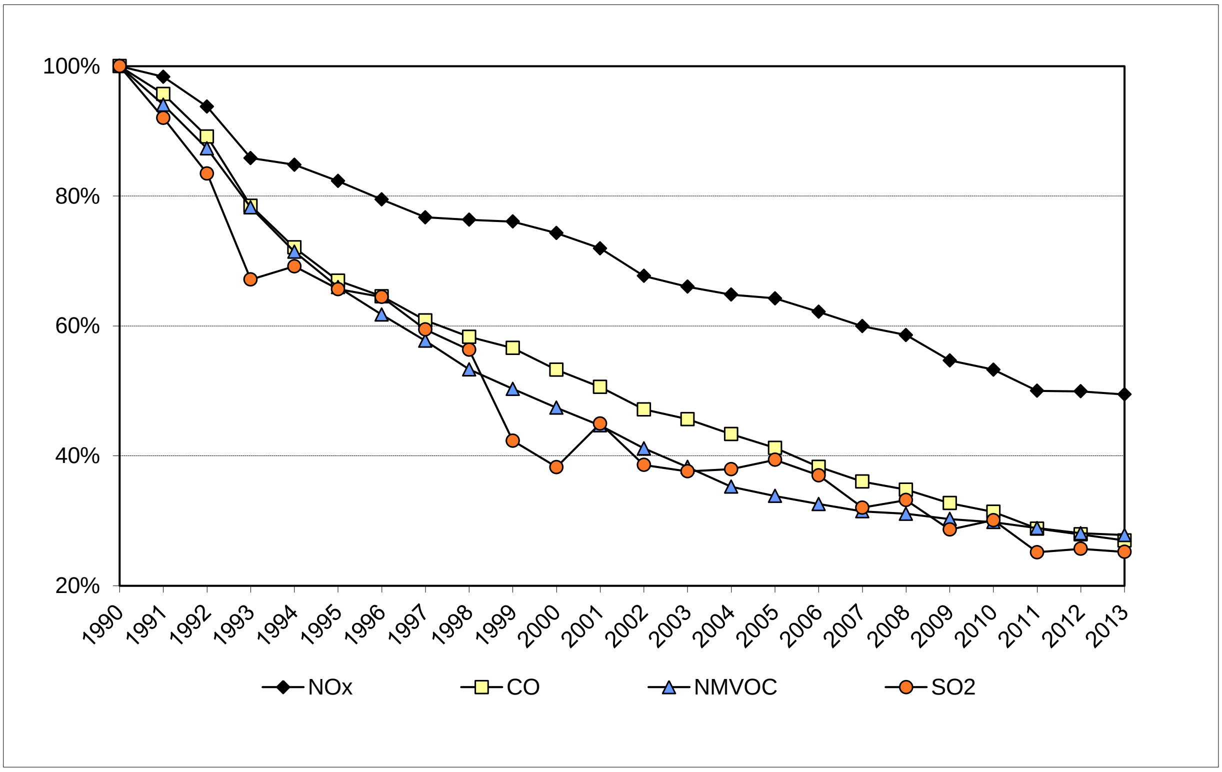


Figure 2-9 Relative trends for indirect GHG and SO_2 emissions (without NMVOC from LULUCF), 1990–2013 (base year 1990 = 100%).

The energy sector was by far the largest source of indirect greenhouse gas emissions (see Table 2-7), with the only exception being NMVOC, where sector 2 Industrial processes accounted for 28.0% of the total emissions. The total shown in Table 2-7 includes NMVOC emissions from LULUCF and HWP, which are estimated at constant 95.5 kt per year (SAEFL 1996a). This corresponds to 53.2% of the total in 2013.

Table 2-7 Indirect GHG and SO_2 emissions (kt) by source, 2013. The total NMVOC emissions including NMVOC from LULUCF.

Sources	**NO_x**	**CO**	**NMVOC**	**SO_2**
	Emissions 2013 (kt)			
1 Energy	67.09	207.61	27.52	9.21
2 Industrial processes	0.37	4.74	50.19	0.78
3 Agriculture	3.03	NO	3.90	NO
4 LULUCF and HWP	IE, NE	IE, NE	95.53	NE
5 Waste	0.39	2.52	2.25	0.09
6 Other sources	0.08	0.80	0.13	0.01
Total	**70.96**	**215.67**	**179.53**	**10.09**

Figure 2-10 shows the relative contributions (excluding LULUCF) of the various sectors for each individual gas (data from Table 2-7). The energy sector can clearly be identified as the main source of NO_x, CO and SO_2.

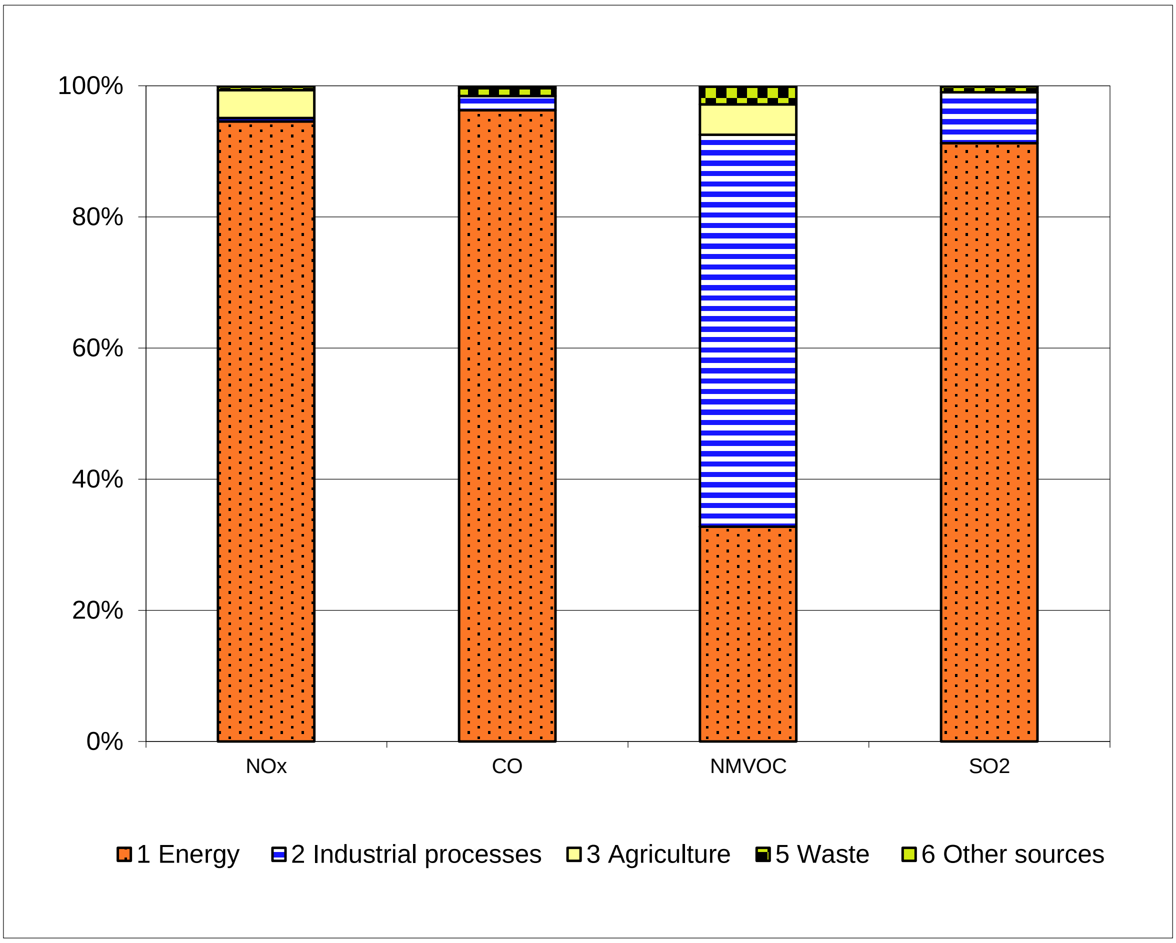


Figure 2-10 Relative contributions of individual sectors to indirect GHG and SO_2 emissions in 2013 (without NMVOC from LULUCF).

2.5 Emission Trends (Kyoto Protocol)

Relevant emission and removals under the Kyoto Protocol are shown in Table 2-8 and Table 2-9, sorted by sectors and gases, respectively. Base year emissions for the second commitment period will be reported in the second initial report.

Table 2-8 Summary of Switzerland's GHG emissions in CO_2 equivalent (kt), 1990–2013 excluding emissions from LULUCF, Other and International bunkers.

		Sector	Base year inital report	1990	1991	1992	1993	1994	1995	1996	1997	1998
			CO_2 equivalent (kt)									
Annex A sources		1 Energy	41'707	41'707	44'177	44'207	42'026	40'890	41'803	42'717	41'749	43'298
		2 Industrial processes	3'522	3'522	3'157	2'997	2'691	2'881	2'873	2'749	2'666	2'782
		3 Agriculture	6'713	6'713	6'674	6'557	6'456	6'440	6'413	6'367	6'182	6'141
		5 Waste	1'355	1'355	1'354	1'324	1'253	1'181	1'173	1'142	1'126	1'103
		Total (Annex A sources)	**53'296**	**53'296**	**55'362**	**55'085**	**52'425**	**51'392**	**52'262**	**52'974**	**51'723**	**53'324**

		Sector	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
			CO_2 equivalent (kt)									
Annex A sources		1 Energy	43'093	42'061	43'489	41'892	43'109	43'457	43'918	43'567	41'526	42'886
		2 Industrial processes	2'845	3'098	3'198	3'235	3'327	3'621	3'775	3'757	3'823	3'904
		3 Agriculture	6'055	6'029	6'089	6'054	5'976	5'954	5'993	6'022	6'076	6'180
		5 Waste	1'076	1'046	1'013	999	947	948	935	960	984	974
		Total (Annex A sources)	**53'068**	**52'233**	**53'789**	**52'180**	**53'359**	**53'979**	**54'621**	**54'305**	**52'408**	**53'943**
KP-LULUCF	Art.3.3	Afforestation & reforestation										-16
		Deforestation										69
	Art.3.4	Forest management										-1'448
		Cropland management										NA
		Grazing land management										NA
		Revegetation										NA
		Harvested wood products (HWP)										-524
		Total (Art. 3.3 + 3.4)										**-1'919**

		Sector	2009	2010	2011	2012	2013	Base year - 2013
			CO_2 equivalent (kt)					%
Annex A sources		1 Energy	41'815	43'192	39'145	40'525	41'452	-1%
		2 Industrial processes	3'796	4'017	4'051	4'056	4'093	16%
		3 Agriculture	6'091	6'108	6'052	6'015	5'949	-11%
		5 Waste	959	981	983	1'013	1'053	-22%
		Total (Annex A sources)	**52'662**	**54'297**	**50'230**	**51'608**	**52'547**	**-1.4%**
KP-LULUCF	Art.3.3	Afforestation & reforestation	-16	-15	-15	-14	-14	
		Deforestation	133	161	161	161	162	
	Art.3.4	Forest management	-2'004	-2'701	-2'600	-2'661	-2'291	
		Cropland management	NA	NA	NA	NA	NA	
		Grazing land management	NA	NA	NA	NA	NA	
		Revegetation	NA	NA	NA	NA	NA	
		Harvested wood products (HWP)	-479	-509	-370	-299	-158	
		Total (Art. 3.3 + 3.4)	**-2'365**	**-3'065**	**-2'823**	**-2'813**	**-2'301**	

Table 2-9 Switzerland's total GHG emissions (excluding LULUCF, Other and International bunkers) and the contribution of individual gases in CO_2 equivalent (kt), 1990-2013.

		GHG	Base year inital report	1990	1991	1992	1993	1994	1995	1996	1997	1998
			CO_2 equivalent (kt)									
Annex A sources		CO_2	44'020	44'020	46'090	45'961	43'545	42'581	43'341	44'076	42'967	44'527
		CH_4	6'168	6'168	6'185	6'071	5'945	5'885	5'864	5'794	5'648	5'568
		N_2O	2'854	2'854	2'847	2'815	2'748	2'717	2'702	2'697	2'601	2'596
		HFCs	0	0	2	16	33	82	246	297	361	456
		PFCs	117	117	99	81	35	21	17	20	21	24
		SF_6	137	137	139	141	121	107	93	90	124	153
		NF_3	0	0	0	0	0	0	0	0	0	0
		Total (Annex A sources)	**53'296**	**53'296**	**55'362**	**55'085**	**52'425**	**51'392**	**52'262**	**52'974**	**51'723**	**53'324**

		GHG	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
			CO_2 equivalent (kt)									
Annex A sources		CO_2	44'351	43'490	44'966	43'353	44'561	45'124	45'718	45'330	43'328	44'645
		CH_4	5'462	5'370	5'358	5'288	5'176	5'127	5'137	5'172	5'192	5'276
		N_2O	2'559	2'554	2'570	2'546	2'498	2'456	2'448	2'448	2'473	2'497
		HFCs	530	625	723	802	897	1'020	1'071	1'118	1'194	1'245
		PFCs	26	50	28	33	62	65	44	52	49	58
		SF_6	140	144	145	158	165	186	203	186	172	222
		NF_3	0	0	0	0	0	0	0	0	0	0
		Total (Annex A sources)	**53'068**	**52'233**	**53'789**	**52'180**	**53'359**	**53'979**	**54'621**	**54'305**	**52'408**	**53'943**
KP-LULUCF	Art.3.3	CO_2										-471
		CH_4										NO
		N_2O										0
	Art.3.4	CO_2										-1'454
		CH_4										1
		N_2O										5
		Total (Art. 3.3 + 3.4)										**-1'919**

		GHG	2009	2010	2011	2012	2013	base year - 2013
			CO_2 equivalent (kt)					%
Annex A sources		CO_2	43'512	45'037	40'970	42'229	43'160	-2%
		CH_4	5'188	5'195	5'152	5'151	5'147	-17%
		N_2O	2'460	2'509	2'459	2'454	2'415	-15%
		HFCs	1'253	1'335	1'415	1'495	1'520	NA
		PFCs	63	65	68	71	52	-55%
		SF_6	180	148	160	209	252	84%
		NF_3	5	8	6	0	0	NA
		Total (Annex A sources)	**52'662**	**54'297**	**50'230**	**51'608**	**52'547**	**-1.4%**
KP-LULUCF	Art.3.3	CO_2	-361	-364	-223	-152	-10	
		CH_4	NO	NO	NO	NO	NO	
		N_2O	0.0	0.0	0.0	0.0	0.0	
	Art.3.4	CO_2	-2'009	-2'707	-2'609	-2'666	-2'296	
		CH_4	0.9	0.6	3.8	0.5	0.5	
		N_2O	4.8	4.7	5.3	4.7	4.7	
		Total (Art. 3.3 + 3.4)	**-2'365**	**-3'065**	**-2'823**	**-2'813**	**-2'301**	

The reported total emissions differ from those reported under the UNFCCC, as sector Other – in addition to LULUCF and international bunkers – is not accounted for under the Kyoto Protocol. On the other hand, activities under article 3.3 (afforestation, reforestation and deforestation) and 3.4 (forest-, cropland- and grazing management and revegetation) are taken into account. Under the elective voluntary activities of Article 3, paragraph 4 of the Kyoto Protocol, Switzerland only accounts for forest management.

3 Energy

3.1 Overview

This chapter provides information on the estimation of the greenhouse gas emissions from the energy sector. The following source categories are reported:

- 1A Fuel Combustion
- 1B Fugitive Emissions from Fuels

In Switzerland, the energy sector is the most relevant greenhouse gas source. In 2013, it emitted 41'452 kt CO_2 equivalent which corresponds to 78.9% of total emissions (52'561 kt CO_2 equivalent, national total without LULUCF). The emissions of the period 1990–2013 are depicted in Figure 3-1.

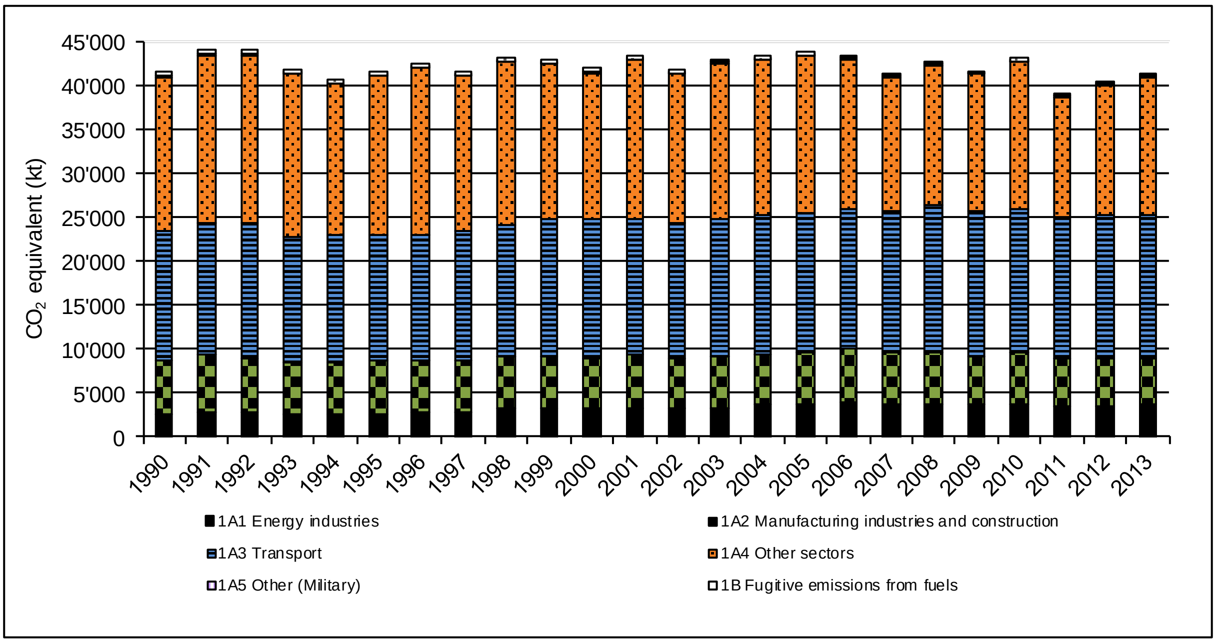


Figure 3-1 Switzerland's GHG emissions of sector 1 Energy 1990–2013 in CO_2 equivalent (kt).

For the total emissions of the energy sector, there are fluctuations up to 6% (100% = emissions 1990) in the period 1990–2013 but no trends. The value 2013 is 0.6% lower than the value of the base year 1990. Four sub-categories dominate the emissions:

- 1A3 Transport and 1A4 Other sectors are the main sources of the sector energy that cover 39.2% and 38.0% of total energy emissions in 2013, respectively.
- 1A1 Energy industries and 1A2 Manufacturing industries and construction are of lesser importance. They contribute 8.9% and 13.0% to the total emissions of the sector energy in 2013, respectively.
- 1A5 Other (Military) and 1B Fugitive emissions only play a minor role. In 2013, they cover 0.3% and 0.6%, respectively, of the total emissions of the sector energy.

The trends of the individual gases are given in the Table 3-1 and Figure 3-2:

- By far the most important gas emitted from the sector energy is CO_2. It accounts for 98.7% of the total greenhouse gas emissions of the sector. Its fluctuations reflect inter alia the climatic variability in Switzerland (see Figure 2-7 and related comments).
- In 2013, CH_4 emissions contributed 0.74% to the total emissions of the sector energy (597 kt CO_2 eq. in 1990, 306 kt CO_2 eq. in 2013). The decreasing trend since 1990 is the result of improved gas transmission network resulting in substantially lower fugitive emissions and reduced emissions from gasoline passenger cars due to catalytic converters. Furthermore improved combustion technologies in 1A4 Other Sectors also contributed to the decreasing trend.
- N_2O contributed 0.56% to the total emissions of the sector energy. The changes in N_2O emissions may mainly be explained by changes in the emission of road transportation due to changes in EFs for diesel and gasoline combustion. The first generation of catalytic converters generated N_2O as undesirable by-product in the exhaust gases, leading to an increase of N_2O emissions until 2000. With new converter materials being used, the emission factors are decreasing since 2001. For further details see chapter 3.2.7.2 b) - 1A3b.

Table 3-1 GHG emissions of source category 1 Energy by gas in CO_2 equivalent (kt), 1990–2013.

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	CO_2 equivalent (kt)									
CO_2	40'814	43'234	43'255	41'094	39'975	40'888	41'796	40'863	42'435	42'256
CH_4	597	628	627	619	601	595	589	555	530	505
N_2O	297	315	325	313	314	320	332	331	333	332
Sum	41'707	44'177	44'207	42'026	40'890	41'803	42'717	41'749	43'298	43'093

Gas	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	CO_2 equivalent (kt)									
CO_2	41'267	42'721	41'171	42'415	42'829	43'309	42'980	40'966	42'323	41'265
CH_4	473	456	429	414	398	384	367	347	342	329
N_2O	320	312	292	281	229	225	219	213	221	221
Sum	42'061	43'489	41'892	43'109	43'457	43'918	43'567	41'526	42'886	41'815

Gas	2010	2011	2012	2013
	CO_2 equivalent (kt)			
CO_2	42'626	38'611	39'994	40'913
CH_4	339	317	304	306
N_2O	227	216	227	233
Sum	43'192	39'145	40'525	41'452

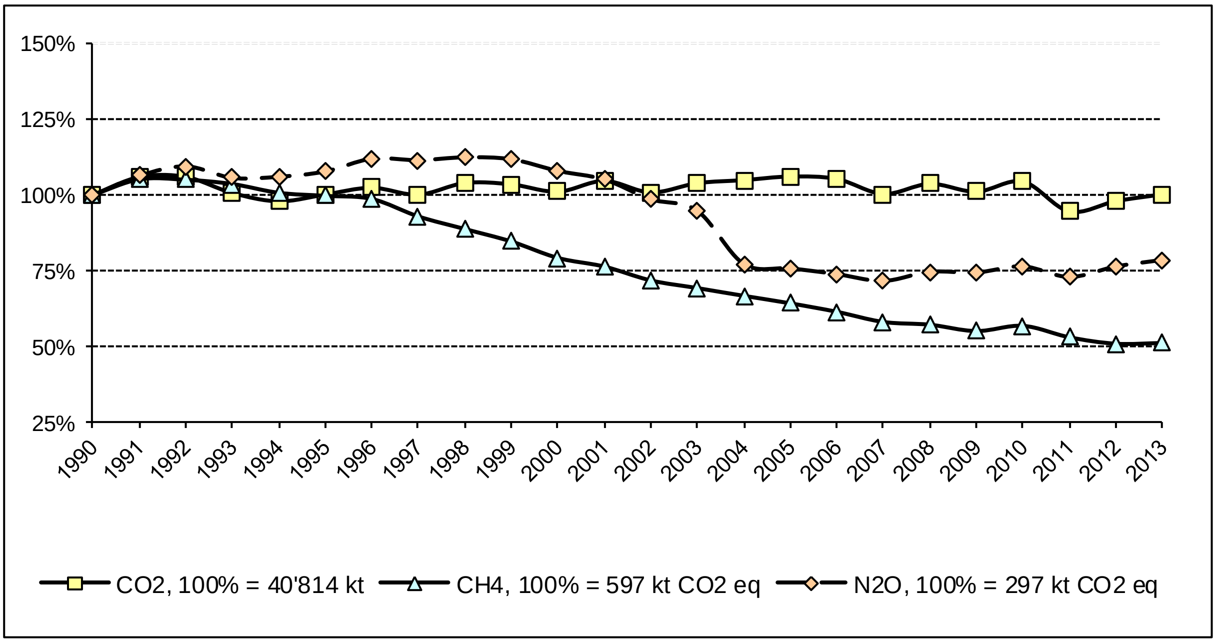


Figure 3-2 Relative trends of the greenhouse gases of source category 1 “Energy” in the period 1990–2013. The base year 1990 represents 100%.

The following table summarises the emissions of the sector energy in 2013. The table includes emissions from international bunkers (aviation and marine) as well as CO_2 emissions from biomass burning which both are not accounted for in the Kyoto Protocol but are contained in the CRF-tables.

Table 3-2 Summary of sector 1 Energy, emissions[2] in 2013 in kt CO_2 equivalent (Total: rounded values).

Emissions	**CO_2**	**CH_4**	**N_2O**	***Total***
	CO_2 equivalent (kt)			
1 Energy	40'913.1	305.6	233.1	*41'452*
1A Fuel Combustion	40'859.2	93.5	232.2	*41'185*
1A1 Energy industries	3'642.7	2.5	32.4	*3'678*
1A2 Manufacturing industries and construction	5'334.0	9.9	33.0	*5'377*
1A3 Transport	16'124.3	22.7	98.3	*16'245*
1A4 Other sectors (Houshold, Commercial, Agriculture)	15'642.5	58.3	67.3	*15'768*
1A5 Other (Military)	115.6	0.1	1.1	*117*
1B Fugitive emissions from fuels	53.9	212.1	0.9	*267*
International bunkers	4'736.8	1.8	45.1	*4'784*
CO_2 emissions from biomass	6'655.1	IE	IE	*6'655*

In 2013, 44 key source categories are identified in the Swiss greenhouse gas inventory (Table 1-10). 20 of which belong to the energy sector. With regard to level, the key categories from the energy sector are depicted in Figure 3-3 (approach 1) and Figure 3-4 (approach 2). Most dominant are the CO_2 emissions from 1A3b Transport (gasoline, CO_2), 1A4b Other Sectors (liquid fuels, CO_2) and 1A3b Transport (diesel, CO_2).

[2] For full biomass CO_2 emissions see Table 3-16.

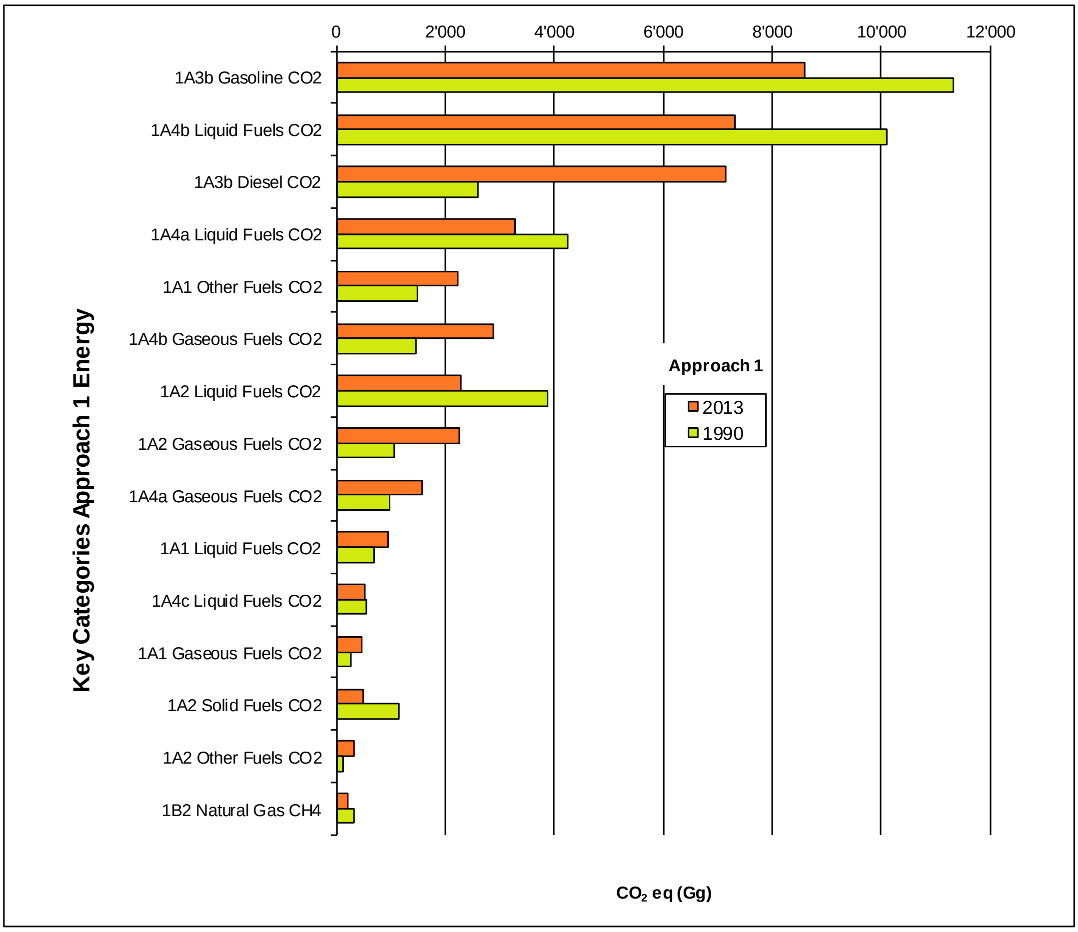


Figure 3-3 Key sources in the Swiss GHG inventory from the energy sector determined by Approach 1.

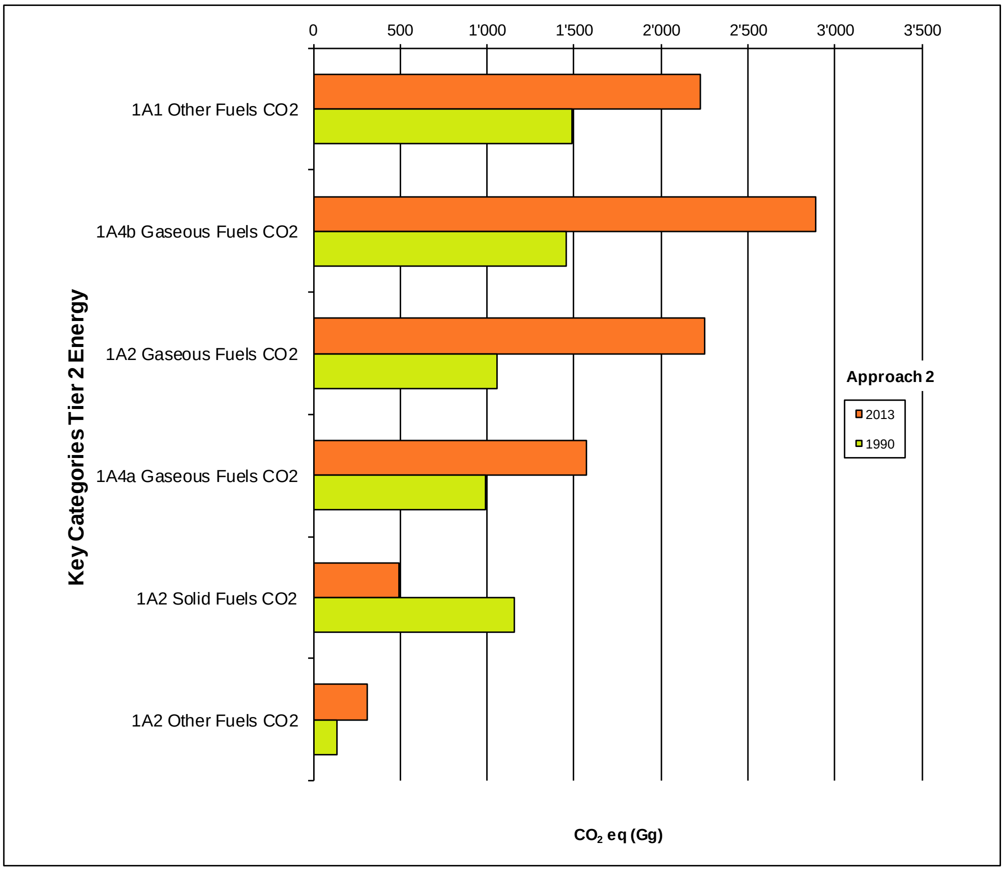


Figure 3-4 Key sources in the Swiss GHG inventory from the energy sector determined by Approach 2.

3.2 Source Category 1A – Fuel Combustion Activities

3.2.1 Comparison of the Sectoral Approach with the Reference Approach

Two methods are applied for modelling CO_2 emissions from the energy sector, the Sectoral Approach and the Reference Approach. For the inventory under the Framework Convention on Climate Change and the Kyoto Protocol the Sectoral Approach is used. The Reference Approach is only used for verification purposes (quality control activity).

Figure 3-5 depicts the two approaches including the input data used and disaggregation of fuel types that ultimately allows for comparing the two approaches.

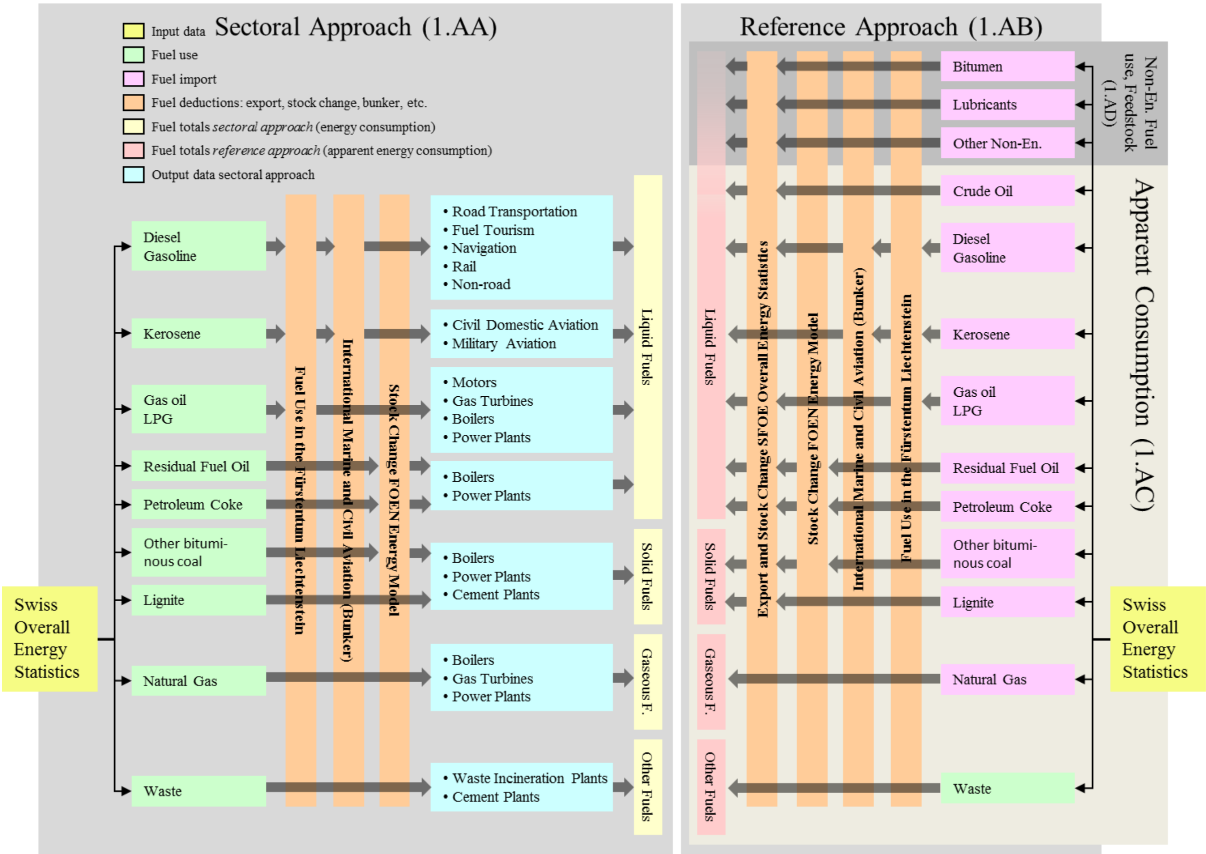


Figure 3-5 Calculation of Reference and Sectoral Approach. The input data for both approaches stem from the Swiss overall energy statistics (SFOE 2014). While the Reference Approach considers the net import/export balance, the Sectoral Approach considers the fuel consumption. The dark grey arrows depict fuel deductions where occurring.

The Sectoral Approach is based on sectoral energy consumption data from the Swiss overall energy statistics (SFOE 2014) and additional source-specific information. In the Sectoral Approach, fossil fuel consumption statistics (top-down approach, Tier 1) are combined with bottom-up data and modelling of fuel consumption (bottom-up, Tier 2 and Tier 3). A detailed description of the Sectoral Approach is provided in chapter 3.2.4.

The Reference Approach on the other hand corresponds to a top-down approach (Tier 1) based on net quantities of fuel imported into Switzerland as listed in the energy supply statistics (SFOE 2014). Apparent consumption (in tonnes) is derived from imports and exports of primary fuels (crude oil, natural gas, coal[3]), secondary fuels (gasoline, diesel oil etc.) and stock changes. For crude oil, a single value for carbon content and net calorific value is applied, although these properties may vary depending on origin. For solid, gaseous, secondary liquid and other fuels, the same carbon content values and net calorific values are applied as in the Sectoral Approach (see Table 3-11 in chapter 3.2.4.2). After the exclusion of feedstocks and non-energy use of fuels (see chapter 3.2.3), the net carbon emissions and the effective CO_2 emissions are calculated for the Reference Approach as reported in the

[3] Coking coal is included under other bituminous coal.

CRF-tables 1A(b)–1A(d). The oxidation factor is set to 1 (see 3.2.4.2). The Reference Approach covers the CO_2 emissions of all net imported primary fuels and emissions of imported secondary fuels. In 2013, 40% of all liquid fossil fuels sold in Switzerland were produced in Swiss refineries (EV 2014).

All necessary data for calculating the Reference Approach are implemented in the EMIS database and all the data on import, export, bunkers, stock changes, apparent consumption, carbon emission factors, carbon stored and actual emissions are calculated within EMIS under the following conditions:

- For the Reference Approach, gas oil and diesel oil are reported together, since the CRF template structure asks for this aggregation. Accordingly a weighted average NCV is calculated and applied here (Table 3-11). In contrast, marine bunkers consist of diesel oil only and are reported using the country-specific NCV of 43.0 TJ/kt.
- Liechtenstein's liquid fossil fuel consumption is subtracted from the input figures in SFOE (2014), as the Swiss energy statistics include Liechtenstein's liquid fuel consumption (see also chapter 3.2.4).

For this submission, the Reference Approach was revised and the calculation of individual fuels for the entire time series was optimized. The differences between Reference and Sectoral Approach are calculated within the EMIS system. The results 1990-2013 are shown in Table 3-3 and in Figure 3-6. For the energy consumption (excluding non-energy use and feedstocks), the differences lie between +1.7% and -1.4%. The difference in 2013 is -0.89%. The corresponding CO_2 emissions from both approaches (excluding non-energy use and feedstocks) also concur very well. For all years, the differences lie between +1.8% and -1.4%. The difference in 2013 is -0.9%.

The difference between Reference and Sectoral Approach is influenced by various effects. The energy and carbon content of crude oil may vary over time. However, no data are available to quantify this effect. Furthermore, the efficiency of Swiss refineries and the market share of secondary fuel imports potentially influence the difference between the Reference and Sectoral Approach. Apparent differences between the Reference Approach and the IEA energy statistics (IEA 2012) are discussed in Annex 4.

Table 3-3 Differences in energy consumption and CO_2 emissions between the Reference and the Sectoral Approach. The difference is calculated according to [(RA-SA)/SA] 100% with RA = Reference Approach, SA = Sectoral Approach. Energy consumption: excluding non-energy use and feedstocks.

Difference between Reference and Sectoral Approach										
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	%									
Energy consumption	0.95	1.60	1.04	1.51	1.51	1.33	1.47	0.76	1.35	0.85
CO_2 emissions	0.92	1.59	1.04	1.62	1.68	1.39	1.53	0.83	1.53	0.88

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	%									
Energy consumption	1.03	1.19	1.22	1.73	1.53	0.14	-0.21	-1.30	-0.76	-1.22
CO2 emissions	1.08	1.25	1.36	1.84	1.69	0.14	-0.16	-1.41	-0.83	-1.25

	2010	2011	2012	2013
	%			
Energy consumption	-1.35	-1.24	-1.17	-0.89
CO2 emissions	-1.43	-1.30	-1.29	-0.91

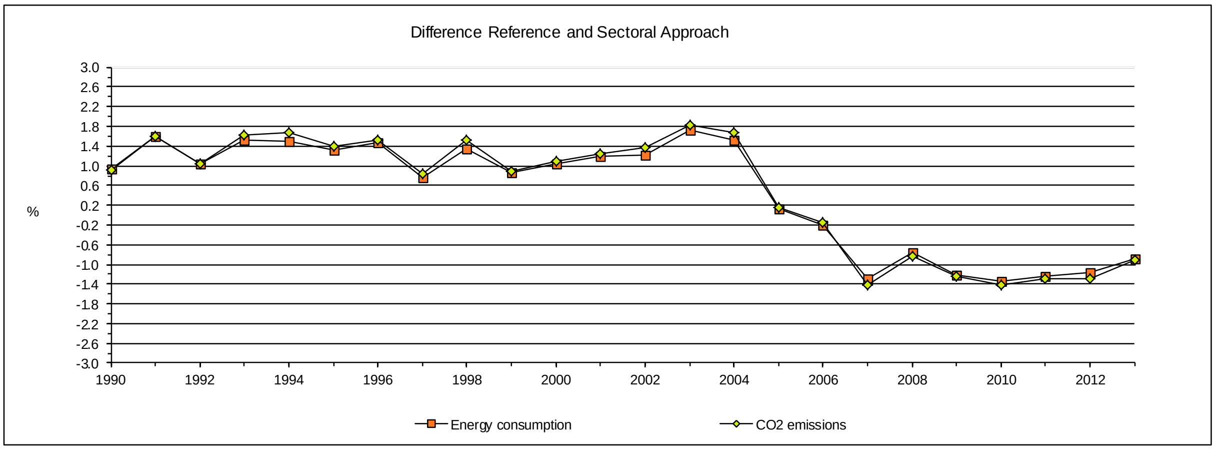


Figure 3-6 Time series for the differences between Reference and Sectoral Approach. Numbers are taken from Table 3-3. See caption in Table 3-3 for further information about how data is calculated.

3.2.2 International Bunker Fuels (1D)

3.2.2.1 Source Category Description

With Switzerland being a landlocked country, international aviation dominates emissions from bunker fuels by far. International navigation is limited to activities on the river Rhine (Basel – Rotterdam) and navigation on Lake Geneva (bordering France) and Lake Constance (bordering Germany and Austria).

Table 3-4 Specification of Swiss source category International Bunkers.

International Bunker Fuels	Specificaitons	Data Source
International Aviation	Country specific model (Tier 3a)	FOCA 2006-2013
International Navigation	Navigation on the Rhine river north of Basel (Tier 1). Navigation on foreign territory on the Lake Geneva and Lake Constance (Bodensee).	SFCA 2014, Schweizerische Bodenseeschifffahrt (SBS), Schifffahrt Untersee und Rhein (Urh), Compagne Générale de Navigation sur le lac Léman (CGN): INFRAS 2011a

3.2.2.2 Methodological Issues

International aviation (aviation bunkers) (1D1)

The emissions from aviation are calculated with a Tier 3a method as described in chapter 3.2.7.2a. The Tier 3a method follows standard modelling procedures on the level of single aircraft movements based on detailed movement statistics. For international aviation (aviation bunkers), those flights are selected, which depart in Switzerland and land at a destination abroad. The emission factors are country-specific. The activity data of the bunker is summarised in Table 3-5 (see also Table 3-39). Given the detailed information about activity data available, the resulting fuel consumption is considered complete. In spite of this, there remain small differences between the fuel consumption modelled bottom-up and the total fuel sold (SFOE 2014). In 1990, the modelled consumption adds up to 1.01 million tons, whereas 1.05 million tons of fuel was sold. Such difference of 4% is considered acceptable, because discrepancies of up to 10% can easily result from fuelling strategies of airlines (FOCA investigation showed that airlines are calculating whether it is economically beneficial to refuel at a place with lower fuel prize). In order to match the bottom up calculation with the fuel quantity sold, any occurring difference is attributed to international bunker emissions. The factor between calculated international fuel consumption and adjusted international fuel consumption is used to scale the bunker emissions linearly. For instance in 1990, the bunker fuel consumption and the emissions had to be expanded by the factor 1.045. For 2006, they had to be reduced by the factor 0.974 (FOCA 2007). For 2013, the correction factor was 0.98 (FOCA 2014). For the more recent years, the modelled and actual total fuel sales are listed in Table 3-5. Table 3-6 provides an overview of total fuel consumption of international aviation (bunker).

Table 3-5 Comparison between modelled and actual fuel sales in bunker fuel consumption for aviation.

Modelled and actual fuel sales	2005	2006	2007	2008	2009	2010	2011	2012	2013
	Fuel consumption in t								
Modelled domestic fuel sales	38'754	38'550	43'968	37'627	39'626	39'252	42'047	43'414	42'064
Modelled international fuel sales	1'152'614	1'196'731	1'287'062	1'391'656	1'345'919	1'395'428	1'511'279	1'527'522	1'528'863
Total modelled fuel sales (FOCA)	1'191'368	1'235'281	1'331'030	1'429'283	1'385'545	1'434'680	1'553'326	1'570'936	1'570'927
Actual fuel sales (GEST)	1'148'131	1'203'868	1'289'152	1'382'835	1'324'224	1'390'824	1'488'805	1'523'116	1'539'963
Difference between FOCA and GEST	3.8%	2.6%	3.2%	3.4%	4.6%	3.2%	4.3%	3.1%	2.0%
Correction factor	0.962	0.974	0.968	0.966	0.954	0.969	0.957	0.969	0.980

Table 3-6 International bunker fuels (1D1): aviation bunkers. Consumption of kerosene in TJ (Note that Liechtenstein's kerosene consumption is subtracted, see chapter 3.2.4).

1D1 International bunker	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	Fuel consumption in TJ									
Total international aviation (1D1)	41'884	40'872	43'499	45'342	46'840	49'918	51'975	53'983	56'599	60'805
1990 = 100%	100%	98%	104%	108%	112%	119%	124%	129%	135%	145%

1D1 International bunker	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	Fuel consumption in TJ									
Total international aviation (1D1)	63'687	60'097	55'468	49'763	46'896	47'671	50'109	53'543	57'844	55'238
1990 = 100%	152%	143%	132%	119%	112%	114%	120%	128%	138%	132%

1D1 International bunker	2010	2011	2012	2013
	Fuel consumption in TJ			
Total international aviation (1D1)	58'118	62'211	63'627	64'709
1990 = 100%	139%	149%	152%	154%

International navigation (navigation bunkers) (1D2)

Emissions from international navigation are calculated with a Tier 1 method. Only diesel oil is concerned, which is consumed by bunkers of navigating the river Rhine (SFCA 2014b) and of navigating two border lakes (Lake Constance, Lake Geneva) for which bunker fuel consumption was reported in INFRAS (2011a) after having performed surveys among the shipping companies involved. The emission factor is country-specific and in accordance with Table 3-11. Activity data of these bunkers is summarised in Table 3-7.

Since there is an exemption from fuel taxation, activity data on marine river bunkers on the Rhine are well documented by the customs administration for the years 1997-2013 (Schiffahrt Untersee und Rhein, URH) as well as by CARBURA, the Swiss organisation for the compulsory stockpiling of oil products (CARBURA 2010) for the years 1990-1996.

Activity data for the marine lake bunkers are not very well documented for the whole time series. For the year 2013 the same activity data as for 2012 was used. Data from 1995-2012 have been provided by the three companies concerned (SBS, URH and CGN) as documented in INFRAS 2011a. For older data, proxies, such as passenger data on a national basis had to be consulted. As marine lake bunkers provide only a minor share of the total international navigation (between 6% for the year 1990 and 23% for 2013) this approach is justified.

Table 3-7 International bunker fuels (1D2): Navigation. Consumption of diesel oil in TJ.

1D2 International bunker	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
	Fuel consumption in TJ									
Total international navigation (1D2)	812	750	765	763	826	755	671	666	544	559
1990 = 100%	100%	92%	94%	94%	102%	93%	83%	82%	67%	69%

1D2 International bunker	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
	Fuel consumption in TJ									
Total international navigation (1D2)	525	426	350	423	426	499	461	475	458	433
1990 = 100%	65%	53%	43%	52%	53%	61%	57%	59%	56%	53%

1D2 International bunker	**2010**	**2011**	**2012**	**2013**
	Fuel consumption in TJ			
Total international navigation (1D2)	470	419	377	354
1990 = 100%	58%	52%	46%	44%

3.2.2.3 Uncertainties and Time-Series Consistency

International aviation: see remarks in Chapter 3.2.7.3, sections Domestic Aviation (1A3a). International navigation: a comparison with the data by CARBURA reveals very high correlation. Therefore, data on international navigation is considered to be consistent.

No quantified data about uncertainties are available.

3.2.2.4 Source-Specific QA/QC and Verification

No source specific QA/QC activities are implemented. General QA/QC procedures are described in chapter 1.2.3.

3.2.2.5 Source-Specific Recalculations

No source specific recalculations in 2014.

3.2.2.6 Source-Specific Planned Improvements

No source-specific planned improvements.

3.2.3 Feedstocks and Non-Energy Use of Fuels

The Swiss overall energy statistics (SFOE 2014) reports feedstocks and non-energy fuel use on an aggregated level only. Some breakdown is provided by the petroleum balance of the annual report of the Swiss Petroleum Association (EV 2014). To complement this source, bottom-up information from individual companies' surveys is used to provide a detailed breakdown into specific petroleum products and coal type. For this submission, a new and more differentiated breakdown of feedstocks and non-energy use of fuels has been developed. The reassessment of feedstocks and other non-energy use of fuels is documented in an internal documentation (FOEN 2015g).

Feedstocks and non-energy use of fuels is reported in CRF-table 1.A(d) and differentiated in the following fuel types:

- Liquefied petroleum gas and naphtha are exclusively used in one single Swiss plant as feedstocks in the thermal cracking process for the production of ammonia and ethylene (see source categories 2B1 and 2B8b). Accordingly, activity data for liquefied petroleum gas and naphtha are confidential and included in fuel type Other oil in CRF-table 1.A(d). For the expert review team, there is a confidential version of this subchapter available which includes all relevant data and information.
- Bitumen is the most important petroleum product which is used as a feedstock in Switzerland. It is mainly used for road paving with asphalt and to a lower extent in asphalt roofing (see source category 2D3).
- Lubricants are used in a variety of processes, including the blending with motorcycle fuel. Use of lubricants is considered partly emissive (see source category 2D1). According to the 2006 IPCC guidelines, 20% of lubricants are oxidized during use (ODU).
- Petroleum coke is used as a feedstock by two consumers only, i.e. for the production of silicium carbide and graphite as well as primary aluminium (up to 2006) in source categories 2B5 and 2C3, respectively. Apart from bottom-up information from these two consumers, top-down information is provided by the Swiss Petroleum Association (EV 2014). Accordingly, activity data are confidential and included in fuel type Other oil in CRF-table 1.A(d). For the expert review team, there is a confidential version of this subchapter available which includes all relevant data and information.
- Paraffin waxes for non-energy use are reported under Other oil, since there is no separate category for paraffin waxes in CRF-table 1.A(d). The information used comes from the statistics of the Swiss Petroleum Association (EV 2014). Use of paraffin waxes is considered partly emissive (see source category 2D2). According to the 2006 IPCC guidelines, 20% of paraffin waxes are oxidized during use (ODU).
- Other oil comprises all other unspecified petroleum products for non-energy use including gasoline (andere Benzine), kerosene (andere Petrole) and white spirit.
- Other bituminous coal is used for the production of silicium carbide and graphite in source category 2B5. As only one company is concerned, activity data are confidential and included in fuel type Other oil in CRF-table 1.A(d). For the expert review team, there is a confidential version of this subchapter available which includes all relevant data and information.

Table 3-8 This table is only available in the confidential version of this chapter. It provides a complete time series of the fuel quantity, carbon excluded and the reported CO_2 emissions from feedstocks and non-energy use of fuels.

Category-specific recalculations

For the first time the following use of feedstocks and non-energy use of fuel is considered in more detail for this submission and differentiated according to the use of Petroleum coke, Paraffin waxes and Other bituminous coal.

Use of Lubricants and Paraffin waxes are newly considered partly emissive according to IPCC Guidelines 2006, as reported in 2D1 and 2D2.

3.2.4 Country-specific issues

In the following chapter, the general country-specific approach of determining activity data and emission factors is presented. Specific information about each source category is included in the respective chapters 3.2.5 to 3.2.9.

3.2.4.1 Activity Data

The energy related activity data in the inventory corresponds to the energy balance provided in the Swiss overall energy statistics (SFOE 2014). It is updated annually and contains all relevant information about primary and final energy consumption. This includes annual aggregated consumption data for various fuels and main consumers such as households, transport, energy industries, industry, and services.

The aggregated data on fuel consumption in the Swiss overall energy statistics is derived from the following sources:

- Carbura and Swiss Petroleum Association (EV) for data on import, export, sales, stocks of oil products and for processing of crude oil in refineries (EV 2014)
- Annual import data for natural gas from the Swiss gas industry association (VSG)
- Annual import data for coal from the customs administration
- Data provided by industry associations

Table 3-9 shows the energy balance in Switzerland for 2013. Energy flow charts for 2013 are given in Annex 4 in Figure A – 2.

A time series of the final energy consumption is depicted in Figure 3-7. The total consumption has increased by 12.8% in the period 1990-2013. Simultaneously significant substitutions occurred: liquid fossil heating fuel consumption decreased by 30.8%, natural gas and transport fuel consumption increased by 90.3% and 18.6%, respectively, and electricity by 27.4%.

Table 3-9 Energy balance for Switzerland 2013 (SFOE 2014) in TJ[4]

			Holzenergie	Kohle	Müll und Industrie-abfälle	Rohöl	Erdöl-produkte	Gas	Wasserkraft	Kern-brennstoffe	Übrige erneuerbare Energien	Elektrizität	Fernwärme	Total
			Energie du bois	Charbon	Ord. mén. et déchets ind.	Pétrole brut	Produits pétroliers	Gaz	Energie hydraulique	Combustibles nucléaires	Autres énergies renou-velables	Electricité	Chaleur à distance	Total
			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Inlandproduktion	Production indigène	(a)	41 970	–	54 720	–	–	–	142 460	–	22 240	–	–	261 390
+ Import	Importation	(b)	2 080	5 700	–	211 440	318 290	129 030	–	271 320	280	130 350	–	1 068 490
+ Export	Exportation	(c)	– 170	0	–	–	– 24 040	–	–	–	–	– 138 970	–	– 163 180
+ Lagerveränderung[1]	Variation de stock[1]	(d)	–	– 30	–	– 90	– 1 180	–	–	–	–	–	–	– 1 300
= Bruttoverbrauch	Consommation brute	(e)	43 880	5 670	54 720	211 350	293 070	129 030	142 460	271 320	22 520	– 8 620	0	1 165 400
+ Energieumwandlung:	Transformation d'énergie:													
• Wasserkraftwerke	• Centrales hydrauliques	(f)	–	–	–	–	–	–	– 142 460	–	–	142 460	–	0
• Kernkraftwerke	• Centrales nucléaires	(g)	–	–	–	–	–	–	–	–271 320	–	89 540	1 270	– 180 510
• konventionell-thermische Kraft-, Fernheiz- und Fernheizkraftwerke	• Centrales thermiques class., chauffage à distance, centrales chaleur-force	(h)	– 1 970	–	– 44 220	–	– 650	– 7 880	–	–	–	9 620	18 430	– 26 670
• Gaswerke	• Usines à gaz	(i)	–	–	–	–	–	0	–	–	–	–	–	0
• Raffinerien	• Raffineries	(j)	–	–	–	– 211 350	210 530	–	–	–	–	–	–	– 820
• Diverse Erneuerbare	• Renouvelables div.	(k)	– 1 450	–	–	–	–	460	–	–	– 4 560	4 300	0	– 1 250
+ Eigenverbrauch des Energiesektors, Netzverluste, Verbrauch der Speicherungen	Consommation propre du secteur énergétique, pertes de réseau, pompage d'accumulation	(l)	–	–	–	–	– 13 780	– 440	–	–	–	– 23 740	– 1 810	– 39 770
+ Nichtenergetischer Verbrauch	Consommation non énergétique	(m)	–	–	–	–	– 20 380	–	–	–	–	–	–	– 20 380
= Endverbrauch	Consommation finale	(n)	40 460	5 670	10 500	0	468 790	121 170	0	0	17 960	213 560	17 890	896 000
Haushalte	Ménages	(o)	21 410	400	–	–	99 510	51 290	–	–	12 620	67 560	7 160	259 950
Industrie	Industrie	(p)	10 700	5 270	10 500	–	22 730	39 760	–	–	1 520	67 560	6 420	164 460
Dienstleistungen	Services	(q)	7 660	–	–	–	42 670	28 000	–	–	3 130	63 540	4 310	149 310
Verkehr	Transport	(r)	–	–	–	–	300 320	1 110	–	–	480	11 310	–	313 220
Statistische Differenz inkl. Landwirtschaft	Différence statistique, y compris l'agriculture	(s)	690	0	0	–	3 560	1 010	–	–	210	3 590	0	9 060

[1] + Lagerabnahme
– Lagerzunahme

[1] + diminution de stock
– augmentation de stock

[4] Note that Liechtenstein's consumption of liquid fuels is included in the numbers (see chapter below on Final Swiss energy consumption).

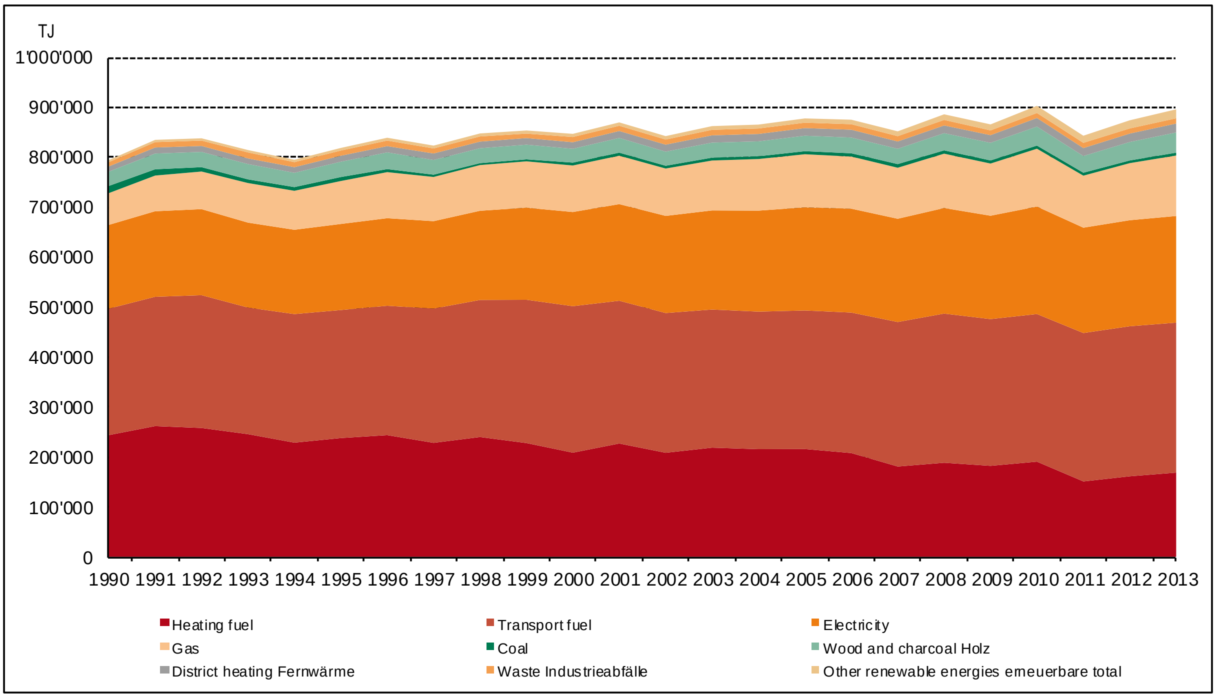


Figure 3-7: Final energy consumption in Switzerland between 1990 and 2013 by fuel type (SFOE 2014). Note that Liechtenstein's consumption of liquid fuels is included in the numbers (see chapter below on Final Swiss energy consumption). It corresponds to 0.31% (1990) and 0.21% (2013) of the Swiss fuel consumption.

Final Swiss energy consumption

The fundamental data on final energy consumption is provided by the Swiss overall energy statistics (SFOE 2014). However, since Switzerland and Liechtenstein form a customs and monetary union governed by a customs treaty, data regarding liquid fuels in the Swiss overall energy statistics also cover liquid fuel consumption in Liechtenstein. In order to calculate the correct Swiss fuel consumption, Liechtenstein's liquid fossil fuel consumption (see Table 3-4 in Liechtenstein's NIR (OE 2015)) is subtracted from the figures provided by the Swiss overall energy statistics. In 2013, the sum of liquid fossil fuels used in Liechtenstein was 1’852 TJ, corresponding to approximately 0.2% of the Swiss consumption of that year.

Disaggregation of the energy consumption

For the elaboration of the greenhouse gas inventory, information about energy consumption is needed at a much more detailed level than provided by the Swiss overall energy statistics. While the total amount of fuel consumption by main energy sources is provided in the Swiss overall energy statistics, additional information sources are used to disaggregate the fuel consumption into the source categories as required for the CRF-tables.

Information on energy consumption and disaggregation is compiled and updated annually in the energy model, which forms an integral part of the emission database EMIS. The following sections provide information for each sector and figures Figure 3-10 to Figure 3-15 show the disaggregation for the main fuel types.

3.2.4.1.1 *Activity Data – 1A1 Energy industries*

The fuel consumption for source category 1A1 is provided by data from the Swiss overall energy statistics (SFOE 2014). Figure 3-10 to Figure 3-15 provide a schematic overview of all sources that are comprised within the Swiss overall energy statistics according to fuel type. As highlighted in these figures, all data on conversion of energy is provided by the Swiss overall energy statistics. The underlying data source for district heating is a statistical data base maintained by SFOE where all relevant installations are registered. Furthermore for wood, respective data source is the wood energy statistics (SFOE 2014b). The residual amount of energy conversion is allocated to electricity production.

3.2.4.1.2 *Activity Data – 1A2 Manufacturing industries and construction*

i) Stationary

For the stationary energy consumption in source category 1A2 Manufacturing industries and construction data sources as listed below are used (see also Figure 3-8 and fuel specific descriptions in Figure 3-10 to Figure 3-15):

- **Swiss overall energy statistics**: The Swiss overall energy statistics (SFOE 2014) has undergone a substantial revision in 2014. It does now provide separate energy consumption data (1990-2013) for households, industry and the commercial/institutional sector, differentiated by fuel types.
- **Helbling statistics**: The Helbling statistics (SFOE, 2014d) refers to robust surveys with members of respective industry associations that are then grossed up or extrapolated to the entire industry branch. For certain sectors and energy sources (e.g. coal) the survey represents a census covering all energy consumed. The surveys are available for all years since 1999 or 2002, depending on the fuel type.
- **Prognos industry model**: The Prognos industry model (Prognos, 2012a) was designed to disaggregate data from the Swiss overall energy statistics. The model is based on 164 individual industrial processes and further 64 processes related to infrastructure in industry. Fuel consumption of a specific process is calculated as the product of the process activity data and the process specific fuel consumption factor. The Prognos model uses the following data sources: i) Consumption data of the Federation of the Swiss pulp, paper and board industry, ii) data from Cemsuisse for 1990 and 2000 to 2011, iii) fuel supply data from CARBURA for 1985 to 2010 (Carbura 2010), iv) data on full-time jobs and on industrial production from the Swiss Federal Statistical Office (SFSO), and v) expert estimates and industry data based on surveys and annual reports from industry associations (Prognos 2013).
- **Bottom-up industry data**: For individual industry branches within source categories 1A2a-d, 1A2f and 1A2giv additional bottom-up data – partly validated and verified monitoring data due to the Ordinance for the Reduction of CO_2 Emissions (Swiss Confederation 2012) – is available and updated annually (see coloured boxes in Figure 3-8 and chapter 3.2.6).
- **Further specific statistical data**: To determine energy consumption in 1A2gviii, further data is taken from the Swiss Wood Energy Statistics (SFOE 2014b) for wood consumption. In addition, data from the Swiss renewable energy statistics (SFOE 2014a) and the Statistics on combined heat and power generation in Switzerland (SFOE 2014c) is used for sewage and biogas.

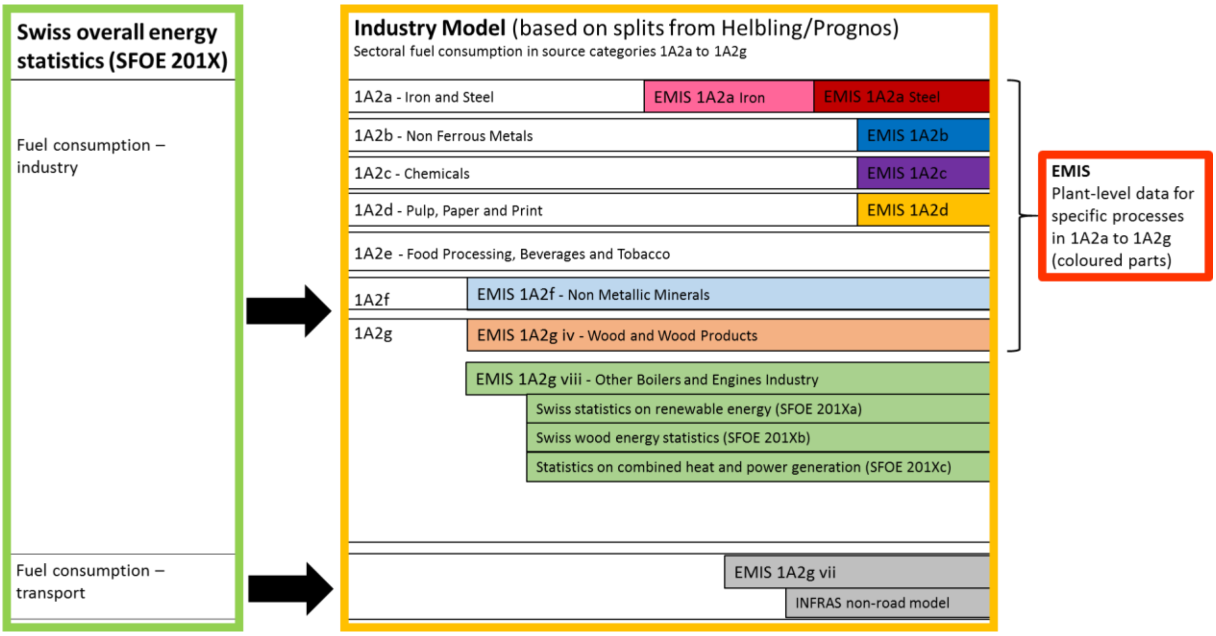


Figure 3-8 Schematic presentation of the data sources used for the industrial sectors 1A2a – g. The reference SFOE 201X refers to SFOE 2014. For each fuel type, the Swiss overall energy statistics provides the total consumption for industry. The total consumption is then distributed to the different source categories based on information from industry surveys (Helbling statistics) and the Prognos industry model. The coloured boxes on the right show the specific bottom-up industry information and statistics from SFOE additionally considered in respective source categories. The signification 201Xa-Xc refers to respective year of the most recent statistic.

For each fuel type, the total energy consumption in the sector industry is provided by the Swiss overall energy statistics, while the Helbling statistics and the Prognos industry model provide estimates of the shares of the individual source categories in 1A2a-1A2f, differentiated by fuel types as well. These shares are used to distribute the total energy consumption of each fuel type (provided by the Swiss overall energy statistics) to the individual source categories. In order to obtain consistent time series of the shares from 1990-2013 data from the Helbling statistics and the Prognos industry model need to be combined, as they do not cover the full time interval individually. For this purpose, the approach to generate consistent time series from overlapping time series is used according to Volume 1, Chapter 5 of the 2006 IPCC Guidelines (consistent overlap). As an illustration, an example for gas oil is provided in Figure 3-9 for source category 1A2e. A detailed description for all fuel types and source categories (1A2a-1A2f), including further assumptions, is provided in EMIS 2015/1A2_Sektorgliederung Industrie.

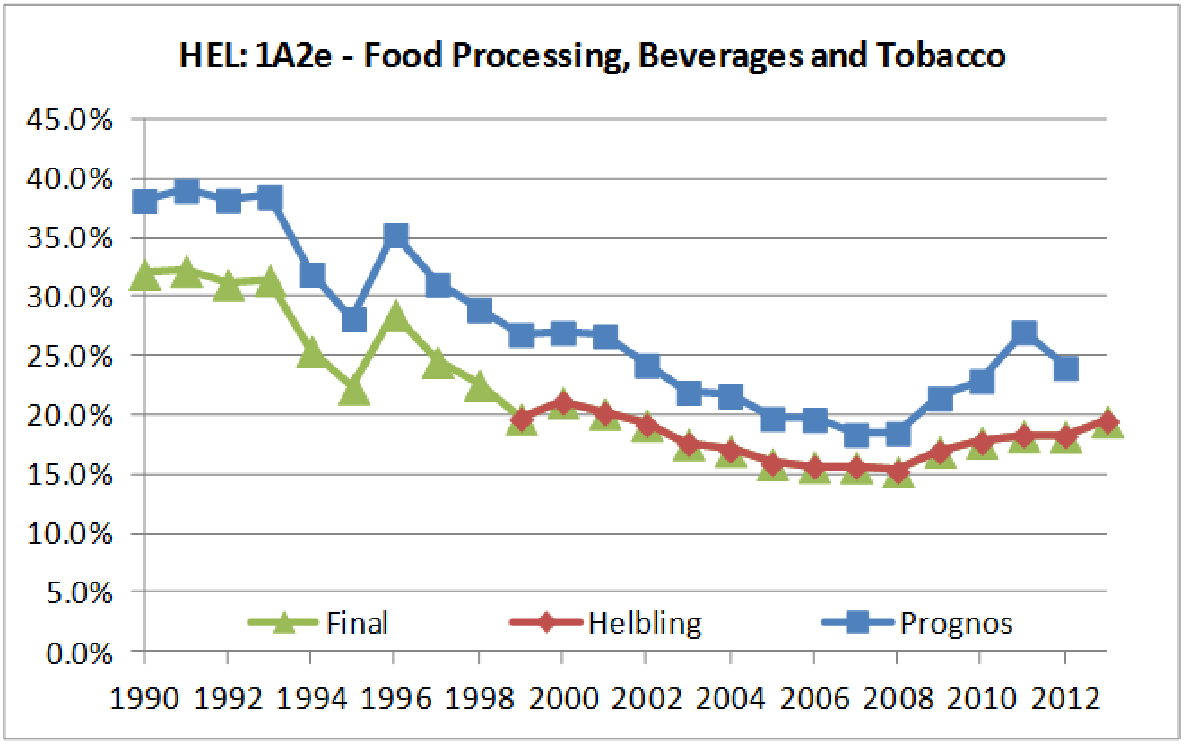


Figure 3-9 Example: Combining time series with consistent overlap. The y-axis indicates the share of source category 1A2e on total industry energy consumption for gas oil. The green line, which is based on the combination according to the 2006 IPCC Guidelines of the shares from the Helbling statistics (red, from 1999 to 2013) and the Prognos model (blue, from 1990 to 2012), corresponds to the share finally used to calculate the energy consumption in 1A2e based on the total industry energy consumption provided by the Swiss overall energy statistics. Similar calculations are performed for each source category and fuel type (EMIS 2015/1 A 2_Sektorgliederung Industrie).

For specific industries, plant-level information is available as discussed in depth in source categories 1A2a, 1A2b, 1A2c, 1A2d, 1A2f and 1A2g (see chapter 3.2.6 and coloured boxes in Figure 3-8). This specific bottom-up information from industries and additional data sources constitutes a subset of the fuel consumption allocated to each source category by the approach described above; the remaining fuel consumption is considered as fuel used in boilers of each source category.

ii) Mobile (1A2gvii)

For the mobile (non-road) machinery (1A2gvii) in sector 1A2 Manufacturing industries and construction consumptions are modelled using a (territorial) emission model developed by INFRAS (2008). The emissions of all non-road categories like construction machines, railways, navigation etc. (1A2gvii, 1A3c, 1A3d, 1A4aii, 1A4bii, 1A4cii, and 1A5) are modelled by the same approach using a Tier 2 method (see 3.2.7.2). Stock and operation hours of the Swiss non-road machine park are differentiated by machine family (i.e. construction, industry, agricultural, military machinery, garden and hobby equipment, diesel rail engines, ships and boats), technology (diesel, 2- or 4-stroke petrol, natural gas, gas oil), power class (in kW) and emission standard. For each segment, load factors, fuel consumption factors and emission factors are assigned. In addition, corrections for degradation and decreasing use with age, deviations from the load factors that measurements are based on, and for dynamic machine use are also considered. The general calculation formula for fuel use and emissions, as well as fuel consumption and emission factors, are shown in Annex A3.1.4. During the complete revision of the emissions of the non-road sector that took place between 2005 and 2008, activity data and emission factors were updated and a new database structured in analogy to the on-road database (INFRAS 2010) was developed for the emission calculation. Emissions are calculated in five-year intervals for 1990 up to 2030. For the years in-between, the emissions are interpolated linearly. A slight modification of the activity data was carried out in 2013 based on the latest numbers on growth of population and economy (Prognos 2012a).

3.2.4.1.3 Activity Data – 1A3 Transport

i) 1A3a Domestic aviation

The emissions of domestic aviation are modelled by a Tier 3a method developed by FOCA (2006) and based on the level of single movements according to detailed movement statistics.

ii) 1A3b Road Transportation

For the remaining transport sector, INFRAS developed an emission model for territorial road transportation (1A3b, INFRAS 2010; for details refer to Annex A3.1.3). The model is based on actual information on driving cycles and vehicle fleets in Switzerland (see also description in 3.2.7.2.

iii) 1A3c Railways and 1A3d Domestic navigation

INFRAS also developed a non-road transport model for non-road transportation in 1A3c and 1A3d (further also in 1A4aii/bii/cii and 1A5) (INFRAS 2008) as described in 3.2.7.2 and 3.2.4.1.2).

The Swiss overall energy statistics provide information on the total amounts of fuel sold. From the amounts sold, the consumptions modelled by the territorial road and non-road models (INFRAS 2008, 2010) are subtracted. The differences to the amount of fuels sold are assigned to the category fuel tourism (i.e. the amount sold in Switzerland but consumed abroad) and statistical difference. Figure 3-10 and Figure 3-15 provide a schematic overview of the disaggregation of the relevant fuels.

iv) 1A3e Pipeline compressors

Fuel consumption for the gas pipeline compressor station in Ruswil (1A3e) is based on the Swiss overall energy statistics (SFOE 2014).

3.2.4.1.4 Activity Data – 1A4 Other sectors

i) Stationary

The revised Swiss overall energy statistics provide separate information on the energy consumption in households and the commercial/institutional and agriculture sector. The statistical differences reported in the Swiss overall energy statistics are allocated to source category 1A4a Other sectors – Commercial/institutional. Energy consumption in households is allocated to source category 1A4b Other sectors – Residential. The share of fuel used for co-generation in turbines and engines within the commercial/institutional and residential sector is derived from a model of stationary engines developed by Eicher + Pauli (Kaufmann 2013) for the statistics on combined heat and power generation (SFOE 2014c). For source category 1A4c Other sectors – Agriculture/forestry/fishing, specific bottom-up industry information is available for grass drying. Its fuel consumption is deducted from the total fuel consumption of 1A2. Figure 3-10, Figure 3-11, and Figure 3-14 provide a schematic overview of the disaggregation of the relevant fuels.

ii) Mobile

Energy consumption in mobile source categories in sector 1A4 Other sectors is based on the INFRAS non-road model (INFRAS 2008). For further details see 3.2.4.1.2, description on source category 1A2, section mobile.

3.2.4.1.5 Activity Data – 1A5 Other

This category comprises only mobile military sources. Fuel consumption in non-road (non-aviation) military is based on the INFRAS non-road model (INFRAS 2008). For further details see 3.2.4.1.2, description on source category 1A2, section mobile . The fuel consumption in military aviation is taken from the logbooks of military aircrafts (DDPS 2014). Figure 3-15 provides a schematic overview of the disaggregation of gasoline and diesel oil into the different source categories.

3.2.4.1.6 Activity data – schematic disaggregation of specific fuel types

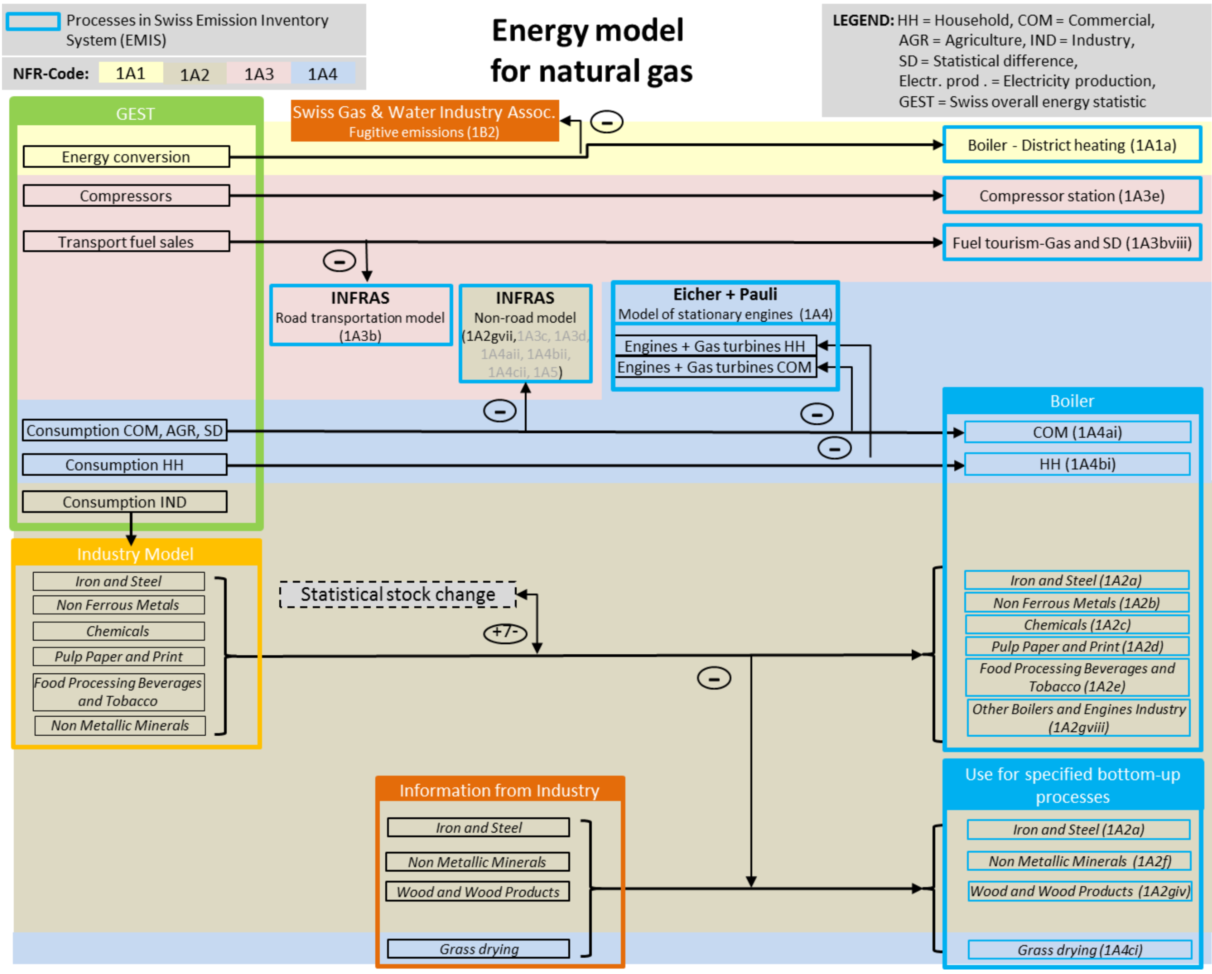


Figure 3-10 Schematic disaggregation of natural gas consumption. For explanations, see chapter 3.2.4.1. Gas losses in the transport and distribution network are based on data from the Swiss Gas and Water Industry Association. Fugitive emissions are reported under source category 1B2b.

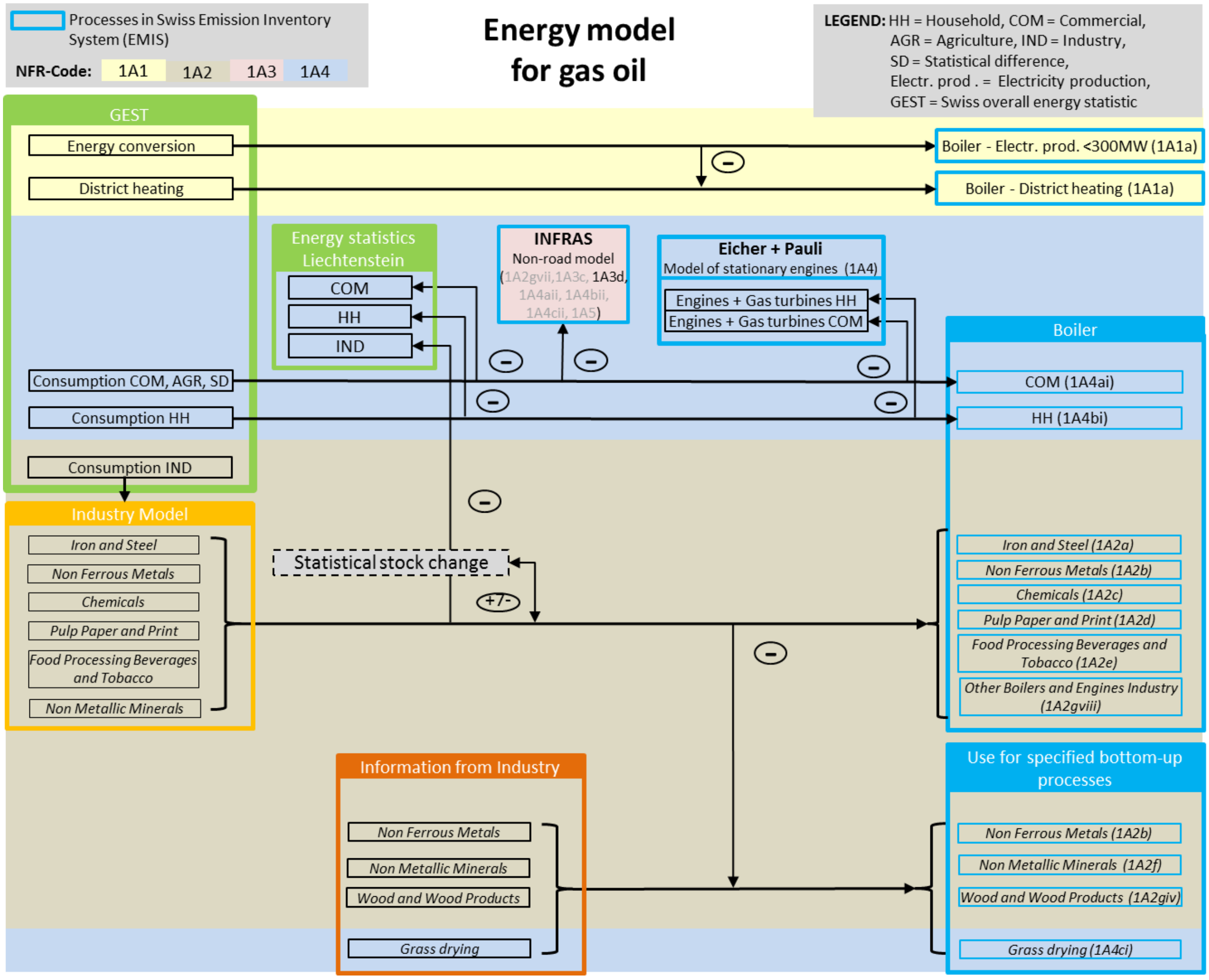


Figure 3-11 Schematic disaggregation of gas oil consumption. For explanations, see chapter 3.2.4.1.1 to 3.2.4.1.4. As the liquid fuels reported in the Swiss overall energy statistics cover Switzerland and Liechtenstein, the liquid fuel consumption of Liechtenstein is subtracted. The small amount of gas oil consumed by steamboats is allocated to source category 1A3d navigation.

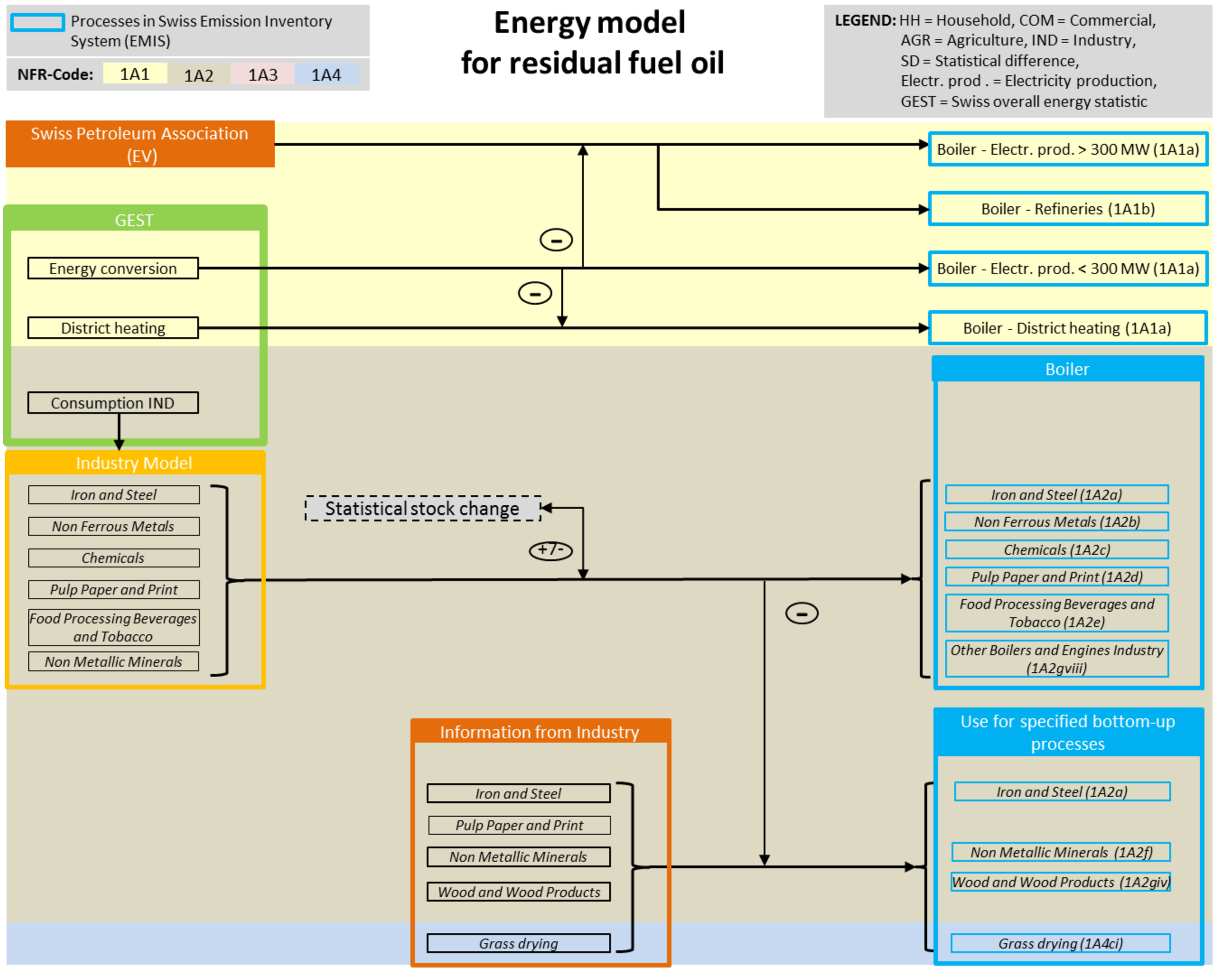


Figure 3-12 Schematic disaggregation of residual fuel oil consumption. For explanations, see chapter 3.2.4.1.

Energy model for petroleum coke, other bituminous coal and lignite

For petroleum coke, other bituminous coal and lignite, an approach similar to the one used for disaggregation of residual fuel oil (Figure 3-12) is used.

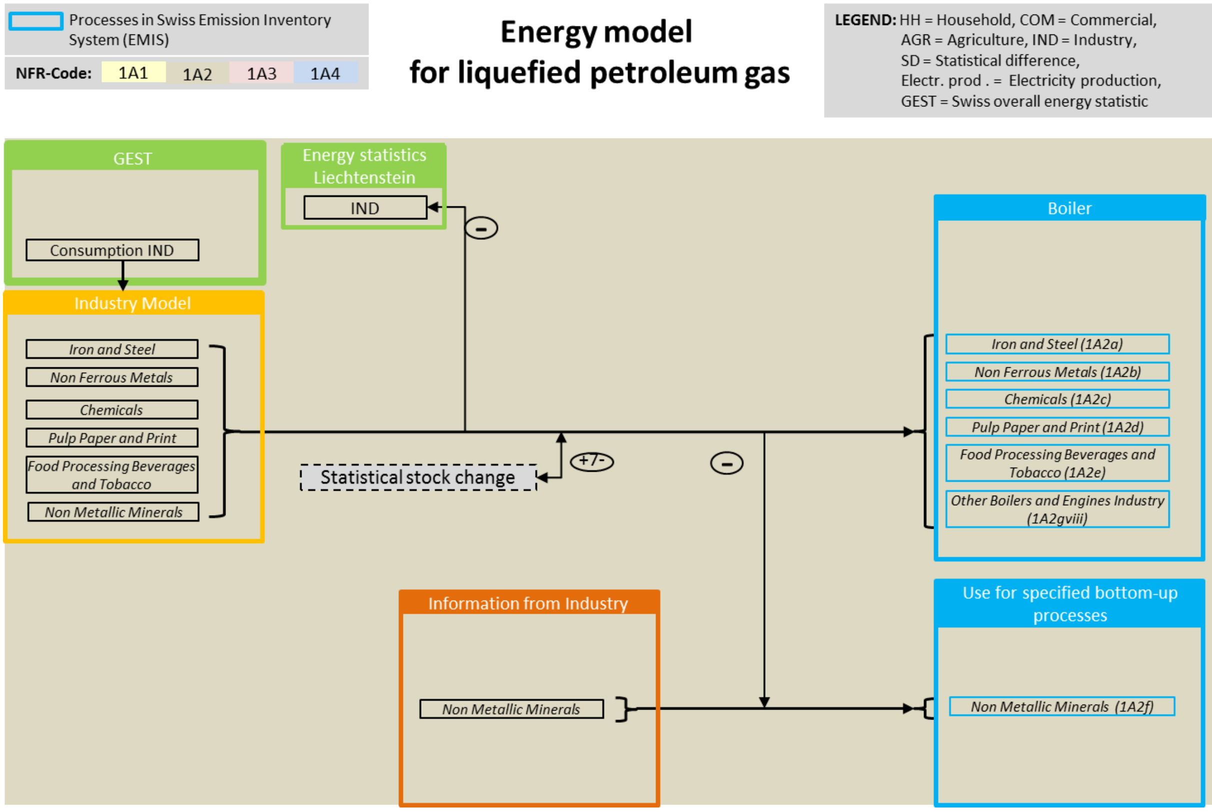


Figure 3-13 Schematic disaggregation of liquefied petroleum gas (LPG) consumption. For explanations, see chapter 3.2.4.1.

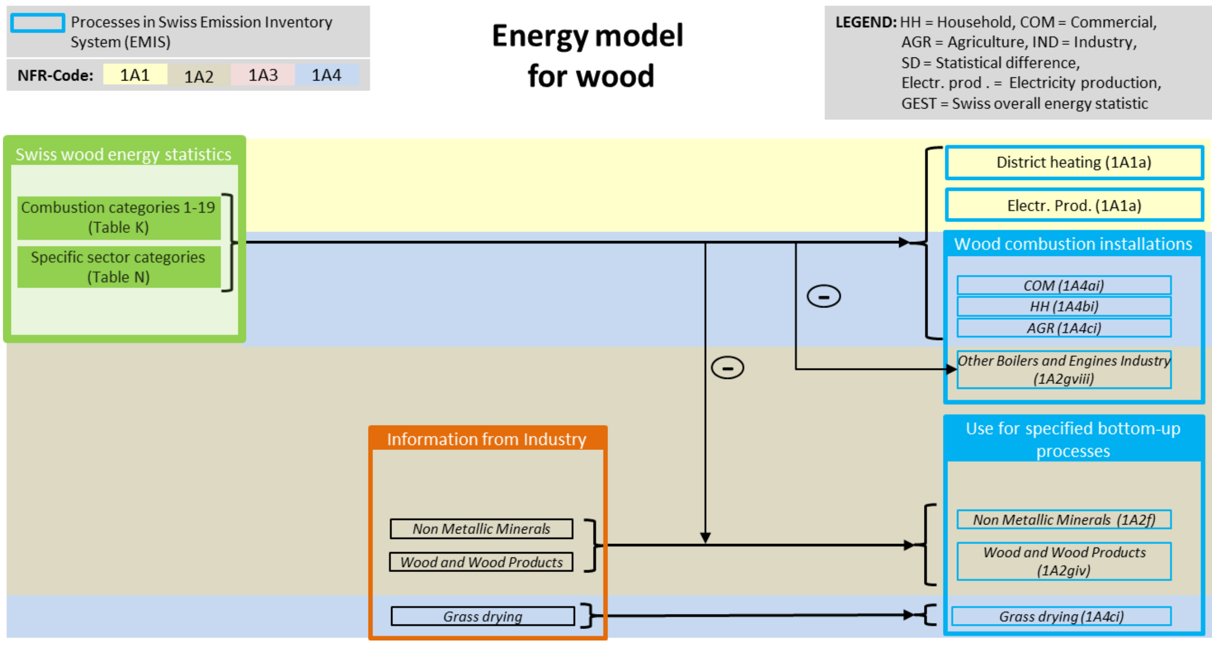


Figure 3-14 Schematic disaggregation of wood consumption.

The Swiss wood energy statistics (SFOE 2014b) provides both the annual wood consumption for specified categories of combustion installations (table K, categories 1-19) and the allocations of the combustion categories to the sectoral consumer categories (table N, household, agriculture/forestry, industry, services, electricity and district heating). This allows for assigning the annual wood consumption on the level of combustion installation categories to the source categories 1A1a Public Electricity and Heat Production, 1A2f Non-metallic minerals, 1A2g Other, 1A4a Commercial/Institutional, 1A4b Residential and 1A4c Agriculture/Forestry/Fishing (see also Table 3-10).

For some industries in source category 1A2f-g, specific bottom-up information is available and included in the energy model (see chapter 3.2.4.1.2). Regarding wood consumption, the specific industry data is subtracted from the activity data of the respective combustion installation category in order to avoid double counting within source category 1A2. The information on the specific processes is documented in the respective EMIS comments (EMIS 2015/1A Holzfeuerungen).

Table 3-10 Categories of wood combustion installations based on SFOE 2014b.

1A Wood combustion, categories
Open fireplaces
Closed fireplaces, log wood stoves
Pellet stoves
Log wood hearths
Log wood boilers
Log wood dual chamber boilers
Automatic chip boilers < 50 kW
Automatic pellet boilers < 50 kW
Automatic chip boilers 50-500 kW w/o wood processing companies
Automatic pellet boilers 50-500 kW
Automatic chip boilers 50-500 kW within wood processing companies
Automatic chip boilers > 500 kW w/o wood processing companies
Automatic pellet boilers > 500 kW
Automatic chip boilers > 500 kW within wood processing companies
Combined chip heat and power plants
Plants for renewable waste from wood products

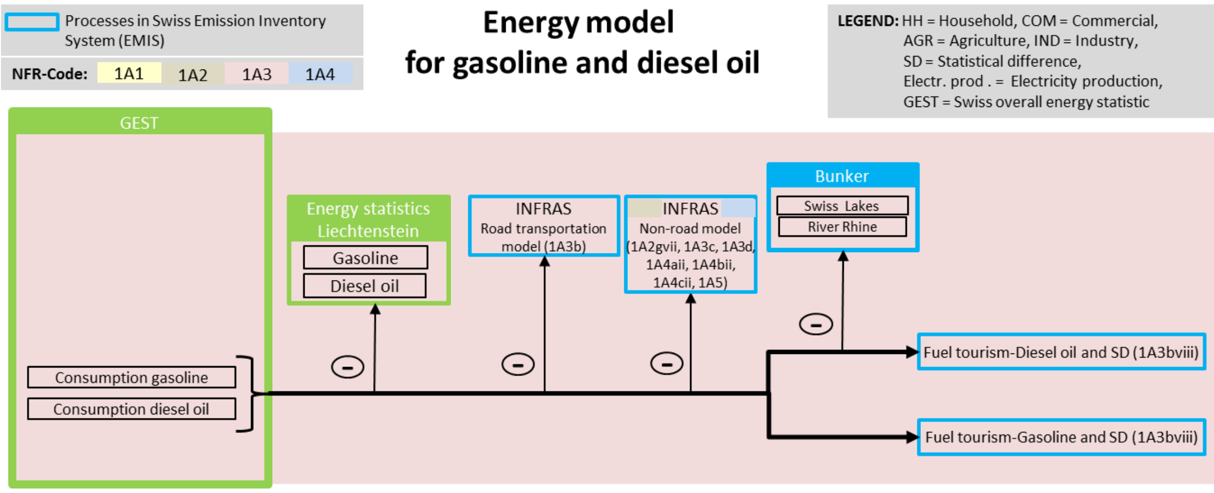


Figure 3-15 Schematic disaggregation of gasoline and diesel oil consumption. For further explanations, see chapter 3.2.4.1 and also 3.2.2 for a detailed description of bunker fuels.

3.2.4.2 Emission Factors

Most sources within source category 1A Fuel combustion are characterised by rather similar combustion processes and thus the same emission factors are applied throughout 1A for the main fuels. Emission factors for particular fuels that are only used in a single source category are described below in the context of the corresponding source category.

CO_2 Emission Factors

Table 3-11 CO_2 Emission factors and NCV from 1990 to 2013.

CO2 Emission Factors and Net Calorific Values 1990 - 2013			1990-1998		2013	
Fuel	**CS/D**	**Data Sources**	**t CO_2 / TJ**	**NCV [GJ/t]**	**t CO_2 / TJ**	**NCV [GJ/t]**
Gasoline	CS	EMPA (1999), SFOE/FOEN (2014)	**73.9**	42.5	**73.8**	**42.6**
Jet kerosene	CS	EMPA (1999), SFOE/FOEN (2014)	**73.2**	43.0	**72.8**	**43.2**
Diesel oil	CS	EMPA (1999), SFOE/FOEN (2014)	73.6	42.8	**73.3**	**43.0**
Gas oil	CS	EMPA (1999), SFOE/FOEN (2014)	73.7	42.6	73.7	**42.9**
Residual fuel oil	CS	EMPA (1999)	77.0	41.2	77.0	41.2
Petroleum coke	CS	Cemsuisse (2010a)	91.4	31.8	91.4	31.8
Liquefied petroleum gas	CS	FOEN (2015d)	65.5	46.0	65.5	46.0
Other bituminous coal	CS	Cemsuisse (2010a)	92.7	25.5	92.7	25.5
Lignite	CS	Cemsuisse (2010a)	96.1	23.6	96.1	23.6
Biofuel	**CS/D**	**Data Sources**	**t CO_2 / TJ**	**NCV [GJ/t]**	**t CO_2 / TJ**	**NCV [GJ/t]**
Biodiesel	CS	assumed equal to diesel oil	**73.6**	42.8	**73.3**	**43.0**
Bioethanol	CS	assumed equal to gasoline	**73.9**	42.5	**73.8**	**42.6**
Wood	CS	SAEFL (2000), SFOE (2014b)	92.0	10.5-14.6	92.0	10.5-14.6

Gasoline, jet kerosene, diesel oil and gas oil

CO_2 emission factors and NCV values are country-specific and based on measurement campaigns of NCV and carbon content. The values for 1990-1998 are assumed constant, as no data are available previous to the first measurements in 1998 (EMPA 1999). From 1999 – 2012, NCV and CO_2 emission factors are linearly interpolated between the measurements in 1998 (EMPA 1999) and a recent study commissioned by the Federal Office for the Environment (FOEN) and the Swiss Federal Office for Energy (SFOE) (SFOE/FOEN 2014). The study is based on a representative sample covering summer and winter fuel qualities from the main import streams. The sampling started in July 2013 for a duration of six months. Samples were taken fortnightly from nine different sites (large-scale storage facilities and the two Swiss refineries) and analysed for carbon content and calorific value. The resulting NCV and CO_2 emission factors are used from 2013 onwards.

Residual fuel oil

Residual fuel oil plays only a minor role in energy supply, therefore this fuel type was not analysed in the most recent measurement study and thus respective values of CO_2 emission factors refer to the measurements by EMPA (1999) for the entire time series.

Natural gas

For natural gas, a country-specific NCV and CO_2 emission factor (Table 3-12) are calculated based on measurements of gas properties and corresponding import shares of individual gas import stations. Measurements of gas properties are available on an annual basis since 2009 and for selected years before that (1991, 1995, 2000, 2005 and 2007). Import shares are available for 2003, 2006, 2009 and from 2011 onwards on an annual basis. For the years 1991, 1995 and 2000 estimated import shares are taken from a study on the gas grid in Switzerland by Quantis (2014). Missing values for the years in between are interpolated.

Table 3-12 Time series of emission factors and NCV of natural gas.

CO2 Emission Factors and Net Calorific Values 1990 - 2013			1990	1991	1992	1993	1994	1995
Fuel	**CS/D**	**Data Sources**	**t CO_2 / TJ**					
Natural gas/Biogas	CS	FOEN (2015h)	56.1	56.1	56.0	55.9	55.8	55.7
			Measured NCV [GJ/t]					
			46.5	46.5				47.5

CO2 Emission Factors and Net Calorific Values 1990 - 2013			1996	1997	1998	1999	2000	2001
Fuel	**CS/D**	**Data Sources**	**t CO_2 / TJ**					
Natural gas/Biogas	CS	FOEN (2015h)	55.7	55.7	55.7	56.0	56.2	56.2
			Measured NCV [GJ/t]					
							47.2	

CO2 Emission Factors and Net Calorific Values 1990 - 2013			2002	2003	2004	2005	2006	2007
Fuel	**CS/D**	**Data Sources**	**t CO_2 / TJ**					
Natural gas/Biogas	CS	FOEN (2015h)	56.3	56.3	56.4	56.4	56.5	56.5
			Measured NCV [GJ/t]					
				46.6		46.3		46.4

CO2 Emission Factors and Net Calorific Values 1990 - 2013			2008	2009	2010	2011	2012	2013
Fuel	**CS/D**	**Data Sources**	**t CO_2 / TJ**					
Natural gas/Biogas	CS	FOEN (2015h)	56.5	56.4	56.4	56.6	56.5	56.4
			Measured NCV [GJ/t]					
						46.1	45.8	45.7

For liquefied petroleum gas, the values are country-specific (NCV: SFOE 2014, CO2-EF: FOEN 2015d).

CO_2 emission factors and NCV values of petroleum coke, other bituminous coal and lignite are country-specific, based on samples taken from Switzerland's cement plants, that are the largest consumer of these fuels in Switzerland. The samples from the individual plants were compiled over nine months and have been analysed for calorific value and carbon content by an independent analytical laboratory. The original data is compiled in an internal document from Cemsuisse. For each fuel, the measurements from the individual plants were weighted according to the relative consumption of each plant. The CO_2 emission factors are lower than the IPCC default values (IPCC 2006), however, they all lie within the range provided by the IPCC.

Regarding the small amount of biofuels used in Switzerland, the CO_2 emission factors and NCV values are assumed equal to the corresponding values of the fossil fuels substituted (i.e. biodiesel – diesel oil, bioethanol – gasoline, biogas – natural gas).

The CO_2 emission factor for wood combustion is country-specific and provided in the handbook of emission factors for stationary sources (SAEFL 2000) as documented in the respective EMIS comment (EMIS 2015/1A Holzfeuerungen). NCV of wood depends on the wood product used as fuel (log wood, wood chips, pellets). The range is displayed in Table 3-11 above and also reported in the Swiss wood energy statistics (SFOE 2014b).

CH_4 Emission Factors

Most CH_4 emission factors are constant over the whole period 1990-2013. Only for wood combustion and road transportation, the CH_4 emission factors are not constant since they decrease over time as a result of improved technology (e.g. improved wood furnaces).

Table 3-13 CH_4 Emission Factors from 1990 to 2013.

CH4 Emission Factors 1990 - 2013			
Fuel	**CS/D**	**Data Sources**	**g CH_4 / GJ**
Gas oil	CS	SAEFL (2000)	1
Residual fuel oil	CS	SAEFL (2000)	4
Petroleum coke	CS	assumed equal to other bituminous coal	10
Liquefied petroleum gas	D	IPCC (2006)	1
Natural gas	CS	SAEFL (2000)	6
Other bituminous coal	D	IPCC (2006)	10
Lignite	D	IPCC (2006)	10
Biofuel	**CS/D**	**Data Sources**	**g CH_4 / GJ**
Wood	CS	Nussbaumer and Hälg (2015)	1.8 - 240

CH_4 emission factors for gas oil, residual fuel oil, and natural gas are country-specific and provided in the handbook of emission factors for stationary sources (SAEFL 2000).

For liquefied petroleum gas, petroleum coke, other bituminous coal and lignite, default values from the 2006 IPCC guidelines are used (IPCC 2006).

The CH_4 emission factors for wood combustion are country-specific. For the categories of wood combustion installations according to the Swiss wood energy statistics (SFOE 2014b) , the emission factors are modelled based on VOC emissions from literature studies and most recent measurements by FID (Nussbaumer and Hälg 2015). For the split of these measured emissions into CH_4 and NMVOC emissions, a factor α of 0.4 ($\alpha = CH_4/VOC$) is applied.

The EF values vary between 1.8 and 240 g CH_4/GJ depending on the year, combustion installation, rated thermal input and technology used. The EF value of a single category represents the emission characteristics of a large number of combustion installations with a range of technology types, maintenance and operating conditions at a given time. According to their lifespan, existing combustion installations are gradually replaced by installations of new technology with better combustion, resulting in a gradually decreasing emission factor. The complete time series of CH_4 emission factors for wood combustion is reported in Table 3-14.

Table 3-14 CH_4 emission factors for wood combustion installations 1990 to 2013.

1A Wood combustion	Unit	CH_4									
		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Open fireplaces	g/GJ	160	158	156	153	151	149	147	144	142	140
Closed fireplaces, log wood stoves	g/GJ	160	158	156	153	151	149	147	144	142	140
Pellet stoves	g/GJ	16.0	15.8	15.6	15.3	15.1	14.9	14.7	14.4	14.2	14.0
Log wood hearths	g/GJ	240	238	236	233	231	229	227	224	222	220
Log wood boilers	g/GJ	200	192	184	177	169	161	153	146	138	130
Log wood dual chamber boilers	g/GJ	240	238	236	233	231	229	227	224	222	220
Automatic chip boilers < 50 kW	g/GJ	20.0	19.3	18.7	18.0	17.3	16.7	16.0	15.3	14.7	14.0
Automatic pellet boilers < 50 kW	g/GJ	6.7	6.5	6.3	6.0	5.8	5.6	5.4	5.1	4.9	4.7
Automatic chip boilers 50-500 kW w/o wood proc. companies	g/GJ	20.0	19.3	18.5	17.8	17.0	16.3	15.6	14.8	14.1	13.4
Automatic pellet boilers 50-500 kW	g/GJ	6.7	6.4	6.2	5.9	5.7	5.4	5.1	4.9	4.6	4.4
Automatic chip boilers 50-500 kW within wood proc. companies	g/GJ	20.0	19.3	18.5	17.8	17.0	16.3	15.6	14.8	14.1	13.4
Automatic chip boilers > 500 kW w/o wood proc. companies	g/GJ	13.3	12.8	12.3	11.8	11.2	10.7	10.2	9.7	9.2	8.6
Automatic pellet boilers > 500 kW	g/GJ	6.7	6.4	6.2	5.9	5.7	5.4	5.1	4.9	4.6	4.4
Automatic chip boilers > 500 kW within wood proc. companies	g/GJ	13.3	12.8	12.3	11.8	11.2	10.7	10.2	9.7	9.2	8.6
Combined chip heat and power plants	g/GJ	13.3	12.8	12.3	11.8	11.2	10.7	10.2	9.7	9.2	8.6
Plants for renewable waste from wood products	g/GJ	13.3	12.8	12.3	11.8	11.2	10.7	10.2	9.7	9.2	8.6

1A Wood combustion	Unit	CH_4									
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Open fireplaces	g/GJ	138	136	133	131	129	127	124	122	120	120
Closed fireplaces, log wood stoves	g/GJ	138	136	133	131	129	127	124	122	120	117
Pellet stoves	g/GJ	13.8	13.6	13.3	13.1	12.9	12.7	12.4	12.2	12.0	12.0
Log wood hearths	g/GJ	218	216	213	211	209	207	204	202	200	193
Log wood boilers	g/GJ	122	114	107	99	91	83	76	68	60	58
Log wood dual chamber boilers	g/GJ	218	216	213	211	209	207	204	202	200	193
Automatic chip boilers < 50 kW	g/GJ	13.3	12.7	12.0	11.3	10.7	10.0	9.3	8.7	8.0	8.0
Automatic pellet boilers < 50 kW	g/GJ	4.5	4.3	4.0	3.8	3.6	3.4	3.1	2.9	2.7	2.7
Automatic chip boilers 50-500 kW w/o wood proc. companies	g/GJ	12.6	11.9	11.1	10.4	9.7	8.9	8.2	7.4	6.7	6.7
Automatic pellet boilers 50-500 kW	g/GJ	4.1	3.8	3.6	3.3	3.0	2.8	2.5	2.3	2.0	2.0
Automatic chip boilers 50-500 kW within wood proc. companies	g/GJ	12.6	11.9	11.1	10.4	9.7	8.9	8.2	7.4	6.7	6.7
Automatic chip boilers > 500 kW w/o wood proc. companies	g/GJ	8.1	7.6	7.1	6.6	6.1	5.5	5.0	4.5	4.0	4.0
Automatic pellet boilers > 500 kW	g/GJ	4.1	3.8	3.6	3.3	3.0	2.8	2.5	2.3	2.0	2.0
Automatic chip boilers > 500 kW within wood proc. companies	g/GJ	8.1	7.6	7.1	6.6	6.1	5.5	5.0	4.5	4.0	4.0
Combined chip heat and power plants	g/GJ	8.1	7.6	7.1	6.6	6.1	5.5	5.0	4.5	4.0	3.6
Plants for renewable waste from wood products	g/GJ	8.1	7.6	7.1	6.6	6.1	5.5	5.0	4.5	4.0	3.6

1A Wood combustion	Unit	CH_4			
		2010	2011	2012	2013
Open fireplaces	g/GJ	120	120	120	120
Closed fireplaces, log wood stoves	g/GJ	113	110	107	103
Pellet stoves	g/GJ	12.0	12.0	12.0	12.0
Log wood hearths	g/GJ	187	180	173	167
Log wood boilers	g/GJ	57	55	53	52
Log wood dual chamber boilers	g/GJ	187	180	173	167
Automatic chip boilers < 50 kW	g/GJ	8.0	8.0	8.0	8.0
Automatic pellet boilers < 50 kW	g/GJ	2.7	2.7	2.7	2.7
Automatic chip boilers 50-500 kW w/o wood proc. companies	g/GJ	6.7	6.7	6.7	6.7
Automatic pellet boilers 50-500 kW	g/GJ	2.0	2.0	2.0	2.0
Automatic chip boilers 50-500 kW within wood proc. companies	g/GJ	6.7	6.7	6.7	6.7
Automatic chip boilers > 500 kW w/o wood proc. companies	g/GJ	4.0	4.0	4.0	4.0
Automatic pellet boilers > 500 kW	g/GJ	2.0	2.0	2.0	2.0
Automatic chip boilers > 500 kW within wood proc. companies	g/GJ	4.0	4.0	4.0	4.0
Combined chip heat and power plants	g/GJ	3.1	2.7	2.2	1.8
Plants for renewable waste from wood products	g/GJ	3.1	2.7	2.2	1.8

For road transportation, the CH_4 emission factors are country-specific; they are calculated as a fraction of hydrocarbon (VOC) emissions, which in turn have been established through specialised measurement programmes (INFRAS 2010, see also Table 3-40, Table 3-41 and Annex Table A-17). The share of CH_4 in VOC emissions is differentiated by a specified emission concept described in INFRAS (2004). For mobile non-road machinery, the CH_4 emission factor is country-specific as well; it is based on VTT (2004) for diesel engines and EMPA (2004) for gasoline two- and four-stroke engines (Table A – 18).

N_2O Emission Factors

Most N_2O emission factors are kept constant over the whole period 1990-2013, with the exception for 1A1a Waste incineration (see Table 3-24) and 1A3b Road transportation. For the latter N_2O emission factors are not constant since they decrease over time as a result of technical improvements such as the further development of catalyst technologies.

Table 3-15 N_2O Emission Factors from 1990 to 2013.

N2O Emission Factors 1990 - 2013			
Fuel	**CS/D**	**Data Sources**	**g N_2O / GJ**
Gas oil	CS	SAEFL (2000)	0.6
Residual fuel oil	CS	SAEFL (2000)	0.8
Petroleum coke	D	IPCC Guidelines 2006	0.6
Liquefied petroleum gas	D	IPCC Guidelines 2006	0.1
Natural gas	D	IPCC Guidelines 2006	0.1
Other bituminous coal	CS	SAEFL (2000)	1.6
Lignite	CS	SAEFL (2000)	1.6
Biofuel	CS/D/D	**Data Sources**	**g N_2O / GJ**
Wood	D	IPCC Guidelines 2006	4

The N_2O emission factors for gas oil, residual fuel oil, other bituminous coal and lignite are country-specific and provided in the handbook of emission factors for stationary sources (SAEFL 2000). N_2O emission factors from the 2006 IPCC Guidelines are applied for liquefied petroleum gas, petroleum coke, natural gas and wood combustion. Specific N_2O emission factors for other fuels are described in the respective source category 1A1a and 1A2f in chapters 3.2.5.2 and 3.2.6 respectively.

For road transportation, N_2O emission factors are taken from the COPERT IV model (Gatzoflias et al. 2012). For mobile non-road machinery, the country-specific N_2O emission factors are based on SAEFL (1996).

Oxidation Factor

For the emission calculation, an oxidation factor of 100% is assumed for all fossil fuel combustion processes, since the technical standards for combustion installations in Switzerland are high and the small fraction of originally non-oxidised carbon retained in ash, particulates or soot is likely to be oxidized later. This is consistent with 2006 IPCC Guidelines and the EU and Swiss guidelines for the Emission Trading System, where also a default oxidation factor of 100% is applied.

3.2.4.3 Emissions from Biomass

CO_2 emissions from biomass do not count for the national total emissions and are therefore a memo item only. The CO_2 emissions from biomass as reported in the CRF-tables are incomplete and the following CO_2 emissions are not foreseen for reporting in the CRF-tables: 2H2 Food and Beverages, 5A Solid waste disposal, 5D Wastewater treatment and discharge and 5B Biological treatment of solid waste.

The following table provides an overview of effective CO_2 emissions from biomass in 2013 and their reporting in the CRF-tables (without land-use, land-use change and forestry). Data regarding waste incineration is provided by FOEN 2014j. Data for CO_2 emissions from wood combustion is provided by the Swiss Wood Energy Statistics (SFOE 2014b) for activity data and from the handbook of emission factors for stationary sources (SAEFL 2000). For combustion of biogas in 2H and 2G, the data is provided by industry and expert estimates as documented in the respective EMIS comment 2015. For combustion of biogas in 1A1a data is provided by SFOE (2014a). In accordance with 2006 IPCC guidelines emissions from flaring on solid waste disposal sites (5A) are considered to be zero. However direct CO_2 emissions from degassing are considered. Data on use of biogas from wastewater treatment and discharge is provided by SFOE (2014a). For further information on the biomass CO_2 emissions refer to the respective source category chapters below.

Table 3-16 Effective biomass CO_2 emissions in 2013 and their representation in the CRF-tables.

Biomass CO_2 emissions	**Unit**	**2013**	**Note**
1A1 Energy industries (without MSW incineration)	Gg	707	Included in CRF
1A1 Energy generation from MSW Incineration	Gg	2'018	Included in CRF
1A2d Use of waste derived fuels in cellulose production	Gg	0	Included in CRF
1A2f Manufacturing industry and construction	Gg	1'231	Included in CRF
thereof use of waste derived fuels in cement production	Gg	54	
1A3 Transport	Gg	47	Included in CRF
1A4 Other sectors (Commercial/institutional, residential)	Gg	2'652	Included in CRF
2H2 Food and beverages industry	Gg	15	Not included in CRF
2G Ohter product use (Consumption of tabacco)	Gg	12	Not included in CRF
5A Solid waste disposal on land	Gg	23	Not included in CRF
5D Wastewater handling	Gg	135	Not included in CRF
5C Waste incineration (without MSW incineration)	Gg	145	Included in CRF
5B Biological treatment of waste (composting and anaerobic digestion)	Gg	355	Not included in CRF
Total biomass combustion CO_2 emissions included in CRF	Gg	6'800	
Total energy related biomass combustion CO_2 emissions included in CRF 1A	Gg	6'655	See table "Summary 2" in CRF
Total biomass CO2 emissions in Switzerland in 2013	Gg	7'340	

3.2.4.4 Uncertainty and time series consistency regarding CO_2 emissions from fuel combustion (1A)

An overview of the uncertainty in aggregated fuel consumption activity data is provided in Table 3-17. For each fuel type, uncertainties of net import or net production data (column C) and uncertainties of stock changes (if applicable) have been estimated. From this, the combined uncertainty of final consumption of fuels has been calculated (column H).

Table 3-17 Details of uncertainty analysis for activity data of fuels in 1A.

A	B	C	D	E	F	G	H
Fuel type	Net import/ net production 2013 [TJ]	Import/ production data uncertainty [%]	Correction for stock changes 2013 etc. [TJ]	Correction uncertainty [%]	Consumption 2013 [TJ]	Final consumption uncertainty 2013 [%]	Comment
Liquid fuels	504'420	1.00	1'270	20	505'690	1.00	1
Gaseous fuels	129'030	5.00	0	0	129'030	5.00	2
Solid fuels	5'670	5.00	30	100	5'700	5.00	3
Other fuels	54'720	10.00	0	0	54'720	10.00	4

Comments:

1 Col. C: Expert estimate from carbura (email M. Ruffer 24.1.05; overall uncertainty has been doubled to account for 95% interval). - Col. E: Conservative interpretation of rough expert estimate from carbura ("one-digit uncertainty", i.e. 10% is one sigma, resulting in unc = 2*sigma = 20%).

2 Col. C: 3%-5% is GL default value for well developed statistical systems (IPCC 2006 Tbl. 2-15).

3 Col. C: 3%-5% is GL default value for well developed statistical systems (IPCC 2006 Tbl. 2-15). Col. E:expert estimate

4 Col. C: An uncertainty of amount of waste of 10% is assumed (expert judgement), because waste input is reasonably well measured since the nineties.

Liquid fuels:

Total uncertainty of net calorific values (NCVs) for liquid fuels is taken as a proxy for the uncertainty of the CO_2 emission factor of liquid fuels. Net calorific values are based on the gross calorific value and the calculation of the net calorific value as determined in the measurement campaign by EMPA (1999). Assuming that this data on the uncertainty of the net calorific value is representative for the uncertainty of the emission factors in fuel combustion, a combined uncertainty defined as two standard deviations results for respective emission factor.

Table 3-18 Details of uncertainty analysis for CO_2 emission factors of fuels in 1A. Relative uncertainties of NCVs are used as proxy for the uncertainty of CO_2 emission factors. Data based on measurement campaign by EMPA (1999).

Fuel	**Net calorific value liquid fuels**					
	Mean [GJ/t]	Standard deviation [GJ/t]	Standard deviation [%]	Uncertainty [%]	No. of samples [--]	Share 2012 (approx.)
Residual fuel oil	41.2	0.85	2.06	4.13	6	0.4%
Gas oil	42.6	0.13	0.31	0.61	10	41%
Diesel oil	42.8	0.10	0.23	0.47	10	27%
Gasoline	42.5	0.29	0.68	1.36	30	31%
Jet kerosene	43.0	0.25	0.58	1.16	10	1%
Sum	42.6				66	100%
Combined St.dev./Unc.			0.25	0.51		

Gaseous fuels:

The uncertainty of the CO_2 emission factor has is not explicitly known, but the uncertainty of the NCV is used as a proxy. The Swiss Gas and Water Industry Association publishes regularly properties of the natural gas used in Switzerland (SGWA 2014). For the NCV a variability range of 3.1% is indicated which is used as uncertainty for the CO_2 emission factor.

Solid fuels:

For the uncertainty of the CO_2 emission factor from 1A1, 1A2 and 1A4, no country-specific uncertainty is available. The 2006 IPCC Guidelines suggests several ranges from 0.5% to 10% (IPCC 2006, Table 2.13) . For Switzerland 5% is chosen (medium of suggested range).

Other fuels (waste to energy):

The dominant factor influencing the uncertainty of CO_2 emissions from municipal solid waste incineration (1A1) is the fossil carbon fraction in the waste. For the carbon content of incinerated waste, an uncertainty of 20% has been estimated, and for the fraction of fossil C in total C an uncertainty of 10% has been estimated, resulting in a uncertainty estimate of 30% for the waste incineration CO_2 emission factor (SAEFL 2005h).

The table Table 3-19 below provides uncertainties of CO_2 emission factors, activity data and CO_2 emissions implemented for uncertainty estimates of the national inventory (based on Approach 1 analysis). The last column contains combined uncertainties as calculated by Approach 1 error propagation.

Table 3-19 Uncertainties of 1A Fuel combustion categories for activity data, emission factors and combined uncertainties. The latter are calculated by Approach 1. (For 1A2/solid fuels and 1A3/gaseous fuels no quantitative emission factor uncertainty is available. The combined uncertainties of 10% or 30% are based on semi-quantitative estimations from Table 1-11. The emission factor uncertainties are then estimated “backward”[5] from the combined and the activity data uncertainty).

1A Fuel Combustion Categories	**Fuel**	**Activity data uncertainty (%)**	**CO_2 Emission factor uncertainty (%)**	**CO_2 Combined Uncertainty (%)**
1. Energy industries	Gaseous Fuels	5.0	3.1	5.9
1. Energy industries	Liquid Fuels	1.0	0.5	1.1
1. Energy industries	Other Fuels	10.0	30.0	31.6
1. Energy industries	Solid Fuels	5.0	5.0	7.1
2. Manufacturing industries and construction	Gaseous Fuels	5.0	3.1	5.9
2. Manufacturing industries and construction	Liquid Fuels	1.0	0.5	1.1
2. Manufacturing industries and construction	Other Fuels	10.0	30.0	31.6
2. Manufacturing industries and construction	Solid Fuels	5.0	29.6	30.0
3. Transport; Domestic aviation	Kerosene	1.0	1.2	1.5
3. Transport; Road transportation	Diesel	1.0	0.5	1.1
3. Transport; Road transportation	Gaseous Fuels	5.0	3.1	5.9
3. Transport; Road transportation	Gasoline	1.0	1.4	1.7
3. Transport; Railways	Liquid Fuels	1.0	0.5	1.1
3. Transport; Domestic navigation	Liquid Fuels	1.0	0.5	1.1
3. Transport; Other transportation	Gaseous Fuels	5.0	8.7	10.0
4. Other sectors; Commercial/institutional	Gaseous Fuels	5.0	3.1	5.9
4. Other sectors; Commercial/institutional	Liquid Fuels	1.0	0.5	1.1
4. Other sectors; Residential	Gaseous Fuels	5.0	3.1	5.9
4. Other sectors; Residential	Liquid Fuels	1.0	0.5	1.1
4. Other sectors; Residential	Solid Fuels	5.0	5.0	7.1
4. Other sectors; Agriculture/forestry/fishing	Gaseous Fuels	5.0	3.1	5.9
4. Other sectors; Agriculture/forestry/fishing	Liquid Fuels	1.0	0.5	1.1
5. Other	Liquid Fuels	1.0	0.5	1.1

[5] $U(EF) = \sqrt{U(EM)^2 - U(AD)^2}$

Data on stock changes are taken from the Swiss overall energy statistics (SFOE 2014; Table 4). Accordingly, also net import/net production data were taken from the Swiss overall energy statistics for the present uncertainty analysis.

Time series for 1A Fuel combustion are all considered consistent.

3.2.4.5 Category-specific QA/QC and verification for source category 1A

Various QA/QC activities are relevant for all source categories in 1A. Therefore, they are briefly described here and not repeated again in the chapters dealing with source-categories 1A1 to 1A5.

Comparison of emission estimates using different approaches

At the level of total energy-related CO_2 emissions, a quality control consists in the comparison of emissions modelled using the Sectoral Approach with emissions calculated based directly on fuel consumption according to the Swiss overall energy statistics. The differences in total CO_2 emissions for the years 1990–2013 are negligible - indicating the completeness of the inventory.

The cross-check of the Reference and Sectoral Approach is also used for an assessment of emissions related to the consumption of fuels in the energy sector. Again, a good agreement between the two approaches is found (see Chapter 3.2.1).

Activity data checks

The SFOE constructs a national commodity balance expressed in mass and in energy units including mass balances of fuel conversion industries (see annex 4).

The gross carbon supply in the Reference Approach has been adjusted for fossil fuel carbon destined for non-energy use. The Swiss overall energy statistics from SFOE (2014) are consistent with those provided by international organisations e.g. IEA (see. annex 4.2).

Emission factor check and review

Emission factors for the main fossil fuels have been reassessed for submission 2015. In 2013, the Federal Office for the Environment (FOEN) and the Swiss Federal Office for Energy (SFOE) launched an in-depth investigation into the NCV and CO_2 emission factors of gas oil, diesel oil, gasoline, and kerosene (SFOE/FOEN 2014). The values differ only marginally from previously used values. The CO_2 emission factors compare well with the IPCC default values (see Table 3-20).

Table 3-20: Comparison of default CO_2 emission factors from IPCC 2006 with country-specific values for selected fuels in 2013.

CO2 Emission Factors	**IPCC 2006**			**Switzerland**
	Lower	Upper	Default	CS
	t CO_2 / TJ			
Gasoline	67.5	73.0	69.3	73.8
Jet kerosene	69.7	74.4	71.5	72.8
Diesel oil	72.6	74.8	74.1	73.3
Gas oil	72.6	74.8	74.1	73.7

As before, the CO_2 emission factor for gasoline is higher than the IPCC range. However, as the value from earlier measurements was confirmed and the new value is based on more than 100 fuel samples taken from July to December 2013, the value is considered to correctly represent national circumstances.

For natural gas, the CO_2 emission factor has been reassessed for submission 2015. A country-specific CO_2 emission factor, based on measurements of gas properties and corresponding import shares of individual gas import stations is calculated. The resulting values are largely consistent with the CO_2 EF used by the countries from which gas is imported (Germany (IEF: 55.5-56.0 t CO_2/TJ), the Netherlands (IEF: 56.5-56.8 t CO_2/TJ), Norway (IEF: 56.1 t CO_2/TJ), France (IEF: 56.0-57.0 t CO_2/TJ), Italy (IEF: 55.3 to 56.9 t CO_2/TJ) and Denmark (IEF: 56.9-57.5 t CO_2/TJ). It lies within the range given by the IPCC (lower 54.3 t CO_2/TJ, upper 58.3 t CO_2/TJ, compared to the country-specific value of 56.4 t CO_2/TJ for 2013).

The CH_4-EF from combustion of wood has been scrutinized and is revised (Nussbaumer and Hälg 2015). The range of country-specific values is not entirely consistent with the upper and lower IPCC default values (Table 3-21).

Table 3-21: Comparison of default CH_4 emission factors from IPCC 2006 with country-specific values

CH4 Emission Factors	**IPCC 2006**			**Switzerland**
	Lower	Upper	Default	CS
	t CH4 / TJ			
Wood	10.0	100.0	30.0	1.8 - 240

Expert review

As described in chapter 1.2.3, data from this source category and the initial draft of the NIR were scrutinized in an external review involving national experts and stakeholders in the different fields related to emissions from stationary sources.

3.2.4.6 Planned Improvements for source category 1A in general

The CH_4 and N_2O emission factors for stationary combustion will be reassessed for submission 2016.

3.2.5 Source Category 1A1 - Energy Industries

3.2.5.1 Source Category Description

Approach 1 Key categories 1A1

CO_2 from the combustion of Liquid fuels (level and trend)
CO_2 from the combustion of Gaseous fuels (level and trend)
CO_2 from the combustion of Other fuels (level and trend)

Approach 2 Key categories 1A1

CO_2 from the combustion of Other fuels (level and trend)

Source category 1A1 Energy industries comprises emissions from fuels combusted by the fuel extraction and energy-producing industries. The most important source category is 1A1a Public electricity and heat production, followed by 1A1b Petroleum refining. Activates in source category 1A1c Manufacture of solid fuels and other energy industries is virtually not occurring in Switzerland (apart from a very small charcoal production activity in traditional and historic trade).

Within source category 1A1a, heat and electricity production in waste incineration plants cause the largest emissions, as electricity production is dominated by hydroelectric power plants (58%) and nuclear power stations (36%) (SFOE 2014). Emissions from industries producing heat and/or electricity (CHP) for their own use are included in category 1A2 Manufacturing Industries and Construction.

Table 3-22 Specification of source category 1A1 Energy Industries.
EMIS 2015/… refers to the internal documentation of the emission database and contains further references regarding specific AD and/or EF.

1A1	Source	Specification	Data Source
1A1a	Public Electricity and Heat Production	Main source are waste incineration plants with heat and power generation (Other fuels) and public district heating systems. The only fossil fuelled public electricity generation unit “Vouvry” (300 MWe; no public heat production) ceased operation in 1999.	Waste incineration: AD: FOEN 2014j; EMIS 2015/1A1a EF: Mohn 2011; Mohn 2013; Rytec 2014, EMIS 2015/1A1a Other sources: AD: SFOE 2014: SFOE 2014a; SFOE 2014b; EV 2014; EMIS 2015/1A1a EF: EMPA 1999; SFOE/FOEN 2014; FOEN 2015d; IPCC 2006; SAEFL 2000; Nussbaumer et al. 2015; EMIS 2015/1A1a; EMIS 2015/1A Holzfeuerungen
1A1b	Petroleum Refining	Combustion activities supporting the refining of petroleum products, excluding evaporative emissions.	AD: EV 2014, SFOE 2014 EF: Refinery gas: Industry data, Petroleum Coke: Cemsuisse (2010a) Residual fuel oil: EMPA (1999)
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Charcoal production	AD: Industry data EF: USEPA (1995), IPCC (2006)

3.2.5.2 Methodological Issues

Public Electricity and Heat Production (1A1a)

For electricity generation, combined heat and power generation as well as heat plants, the following fuels are used in Switzerland:

- Gas oil, residual fuel oil, natural gas and coal (liquid, gaseous, solid fuels)
- Biomass, including wood, renewable waste, and biogas from landfills and anaerobic digestion at biogas facilities (biomass)
- Waste-to-energy through the incineration of municipal solid waste and special waste (other fuels).

Methodology

The method applied within Public electricity and heat production (1A1a) is country-specific.

As explained in chapter 3.2.4.1.1 a country-specific Tier 2 top-down approach based on aggregated fuel consumption data from the Swiss overall energy statistics is used to calculate emissions. For waste incineration, direct data from the incineration plants is used.

Emissions of GHGs are calculated based on the following methodology:

- For fossil fuel combustion, GHG emissions are calculated by multiplying fuel consumption (in TJ) by emission factors.
- For fermentation engines and co-generation on landfills, GHG emissions are calculated by multiplying quantities of combusted CH_4 by emission factors.
- For wood and renewable wastes from wood products, GHG emissions are calculated by multiplying the used wood chips and wood waste quantities by respective emission factors.
- For municipal solid waste and special waste incineration plants, GHG emissions are calculated by multiplying the waste quantities incinerated by emission factors.

Emission Factors

The following table presents the emission factors used in 1A1a. Emission factors for gas oil, residual fuel oil, petroleum coke and natural gas are further explained in section 3.2.4.2.

Table 3-23 Emission Factors for 1A1a Public Electricity and Heat Production in 2013.

1A1a Public electricity and heat production	CO_2	CO_2 bio.	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
	t/TJ	t/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ
Gas oil	73.7	NA	1.0	0.6	35	7	2.0	21
Residual fuel oil	77.0	0	4.0	0.8	125	12	4.0	291
Petroleum coke	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	56.4	NA	6.0	0.1	18	10	2.0	0.5
Other (waste-to-energy), fossil	88.9	NA	NA	1.7	33	7	1.1	4
Other (waste-to-energy), biogenic	NA	92.8	NA	1.4				
Biomass (wood, renewable waste)	NA	92.0	1.8	4.0	122	133	2.7	20
Biogas (co-generation from landfills, fermentation engines)	NA	100.0	2	0.1	48	66	3.0	15

Emission factors for waste incineration

Specific emission factors apply for 1A1a Public electricity and heat production for municipal solid waste incineration. These specific emission factors are relevant for source category 1A1a iv Other – Waste incineration and waste disposal. The emission factors for CO_2, N_2O, NO_x, CO, NMVOC and SO_2 emissions per ton of waste incinerated are country-specific and based on measurements and expert estimates, as documented in EMIS 2015/1A1 Kehricht- und Sondermüllverbrennungsanlagen.

Source-specific CO_2 emission factors for municipal waste incineration

C-content of waste is calculated based on the net calorific value (NCV), which is deduced by a standard method and published on a yearly basis since 2009 by SFOE for each MSWIP and as a Swiss average (FOEN/SFOE/VBSA, 2014). In deviation from the general description of oxidation factors in 3.2.4.2, here an oxidation factor of 0.99 is assumed.

For this submission, the fossil and biogenic CO_2 EF of MSWIPs have been revised, using newly determined C-content of wastes (FOEN 2014l) and an improved time-series of the fossil fraction (Rytec 2014). The study uses data from three measurement campaigns during which the waste composition has been analysed (FOEN 2014o) and measurements of the 14C in the flue gas for calibration (Mohn 2011). Based on this information, the share of organic matter in the waste incinerated in MSW incineration plants is estimated to be 52.2% in 2013 (see documentation in EMIS 2015/1A1a Kehrichtverbrennungsanlagen). The share of fossil/biogenic is then used to split the activity data into biomass and other fuels. The CO_2 emission factor in MSWIPs fluctuates over the period 1990-2013 because of gradual changes in the net calorific values of the waste.

Source-specific CO_2 emission factors for carbonate use in municipal waste incineration

The data for EF CO_2 geogenic are based on the stoichiometric composition. Since both calcium carbonate and sodium bicarbonate are applied, the emission factor is not constant. A conversion factor of 100 % is assumed for both carbonates. During the time period 1990-2006 only calcium carbonate is applied in flue gas treatment of MWI plant. Therefore the emission factor of 0.43971 t CO2/ t calcium carbonate according to 2006 IPCC Guidelines is applied (IPCC 2006). Between 2007-2012 carbonate in flue gas treatment of MWI plants was not applied. In 2013 a MWI plant used bicarbonate in the flue gas treatment. Therefore the emission factor of 0.523880 t CO2/ t sodium bicarbonate is derived from the stoichiometry of sodium bicarbonate (EMIS 2015/1A1a Kehrichtverbrennungsanlagen).

Source-specific CO_2 emission factors for Special waste incineration

For the years 1992-2004 the composition of special waste was known quite well thanks to information in the Swiss waste statistics. Based on information on the composition of the special waste and emission factors for the specific waste fractions a weighted average emission factor for special waste incineration is calculated. Special waste is assumed to be of entirely fossil origin. Overall a specific emission factor of 1.45 t CO_2/t results for special waste. This value is considerably higher than the one reported in SAEFL (2000). As there is no newer data on the special waste composition the emission factor deduced as described above is used for the whole period from 1990 until today. See documentation in EMIS 2015/1A1a Sondermüllverbrennungsanlagen.

Source-specific CH_4 emission factors

Emissions of CH_4 are not occurring because of the high combustion temperatures in waste incineration plants as confirmed by Mohn (2013). The same fact applies for special waste incineration.

Source-specific N_2O emission factors for municipal waste incineration

In 2013, a study evaluated N_2O measurements that have been performed in the years 2010-2011 in the flue gas of five Swiss municipal waste incineration plants (Mohn 2013) and derived plant-specific emission factors for SCR and SNCR-equipped installations.

Average Swiss emission factors have been calculated according to the state of equipment of all Swiss waste incineration plants (with two types of Denox-equipment (SCR, SNCR[6]) and without Denox-equipment). For installations without Denox-equipment the emission factors comes from (SAEFL 2000). According to the state of equipment of all Swiss waste incineration plants in the years 1990, 1994, 1998, 2004, 2008 and 2012, weighted average N2O emission factors have been calculated, based on the amounts of waste burnt in every plant. For the years in between, the N2O emission factor was linearly interpolated. It is planned to calculate a new value every four years, i.e. in submission 2018 based on the amounts of waste burnt in 2016. See documentation in EMIS 2015/1A1a Kehricht- und Sondermüllverbrennungsanlagen. The emission factor is not constant over time; it decreases from 5.3 g/GJ in 1990 to 1.4 g/GJ in 2008. Since then it shows a slight increase.

[6] SCR: Selective Catalytic Reduction, SNCR: Selective Non-Catalytic Reduction

Source-specific N_2O emission factors for special waste incineration

The emission factor of special waste for the year 1990 is based on SAEFL (2000).. It is assumed that this value (3.1 g/GJ) then increases until 2003 (6.1g/GJ) due to the installation of Denox-equipment and thereafter declines as a result of optimized installations.

Table 3-24 N_2O emission factors of 1A1a Municipal solid and special waste incineration and CO_2 emission factors for carbonate use.

1A1a Public electricity and heat production, Other fuels	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
N_2O (MSWIP)	g/GJ	5.26	4.76	4.22	3.67	3.13	2.96	2.79	2.55	2.32	2.21
N_2O (SWIP)	g/GJ	3.06	3.29	3.53	3.76	4.00	4.23	4.47	4.70	4.94	5.17
CO_2 (carbonate use in MSWIP)	g/t	439'710	439'710	439'710	439'710	439'710	439'710	439'710	439'710	439'710	439'710

1A1a Public electricity and heat production, Other fuels	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
N_2O (MSWIP)	g/GJ	2.06	1.91	1.78	1.61	1.46	1.44	1.41	1.40	1.38	1.41
N_2O (SWIP)	g/GJ	5.41	5.64	5.88	6.11	5.80	5.48	5.16	4.84	4.53	4.21
CO_2 (carbonate use in MSWIP)	g/t	439'710	439'710	439'710	439'710	439'710	439'710	439'710	NO	NO	NO

1A1a Public electricity and heat production, Other fuels	Unit	2010	2011	2012	2013
N_2O (MSWIP)	g/GJ	1.40	1.40	1.43	1.44
N_2O (SWIP)	g/GJ	3.89	3.57	3.25	2.94
CO_2 (carbonate use in MSWIP)	g/t	NO	NO	NO	523'880

Activity Data

Activity data for liquid, gaseous, solid fuels and wood are based on the Swiss overall energy statistics (SFOE 2014) and additional data sources as described in 3.2.4.1.1. Activity data for Other fuels are based on the amount of waste incinerated in MSWIPs and SWIPs (FOEN 2014j, see Table 3-26). Activity data for co-generation in landfills and in biogas facilities are taken from the Swiss renewable energy statistics (SFOE 2014a).

Table 3-25 Activity data in 1A1a Public Electricity and Heat Production.

1A1a Public electricity and heat production	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total fuel consumption	TJ	40'937	42'308	44'213	39'422	38'911	39'877	42'796	43'576	48'788	49'872
Gas oil	TJ	980	1'790	1'917	1'662	810	554	810	1'065	852	1'070
Residual fuel oil	TJ	3'195	5'006	6'336	1'748	1'541	1'791	2'420	1'063	4'093	1'211
Petroleum coke	TJ	0	0	0	0	0	0	0	0	0	0
Natural gas	TJ	4'927	5'425	5'425	5'420	5'510	6'112	7'369	7'692	7'494	9'729
Other bituminous coal	TJ	484	102	76	51	76	51	0	0	0	0
Lignite	TJ	0	0	0	0	0	0	0	0	0	0
Other (waste-to-energy), fossil	TJ	16'605	16'004	16'379	16'136	16'622	16'870	17'420	18'504	20'270	21'079
Other (waste-to-energy), biogenic	TJ	14'163	13'365	13'306	13'459	13'258	13'394	13'491	14'157	15'015	15'705
Biomass (wood, renewable waste)	TJ	301	297	360	404	441	466	636	466	431	412
Biogas (co-generation from landfills, fermentation engines)	TJ	282	320	414	542	653	639	650	629	633	665

1A1a Public electricity and heat production	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total fuel consumption	TJ	50'507	52'373	53'245	54'265	55'397	57'607	60'940	58'608	59'816	58'842
Gas oil	TJ	790	840	810	1'060	790	1'300	1'280	843	490	540
Residual fuel oil	TJ	325	390	386	442	351	290	309	215	173	130
Petroleum coke	TJ	0	0	0	0	0	0	0	0	0	0
Natural gas	TJ	8'804	9'116	9'305	10'134	10'193	10'204	9'021	8'261	8'803	8'397
Other bituminous coal	TJ	0	0	0	0	0	0	0	0	0	0
Lignite	TJ	0	0	0	0	0	0	0	0	0	0
Other (waste-to-energy), fossil	TJ	22'482	23'176	23'606	23'358	23'999	24'711	26'940	25'791	25'880	24'853
Other (waste-to-energy), biogenic	TJ	16'889	17'633	17'879	17'941	18'786	19'797	21'940	21'415	21'464	21'249
Biomass (wood, renewable waste)	TJ	547	583	689	774	813	844	939	1'458	2'311	2'877
Biogas (co-generation from landfills, fermentation engines)	TJ	671	634	570	556	465	461	511	626	695	796

1A1a Public electricity and heat production	Unit	2010	2011	2012	2013
Total fuel consumption	TJ	63'031	61'216	65'011	63'372
Gas oil	TJ	500	410	800	650
Residual fuel oil	TJ	51	17	8	46
Petroleum coke	TJ	0	0	0	0
Natural gas	TJ	10'276	7'838	8'455	8'312
Other bituminous coal	TJ	0	0	0	0
Lignite	TJ	0	0	0	0
Other (waste-to-energy), fossil	TJ	26'002	25'575	26'262	25'067
Other (waste-to-energy), biogenic	TJ	22'275	22'272	23'051	21'756
Biomass (wood, renewable waste)	TJ	2'958	3'982	5'032	5'948
Biogas (co-generation from landfills, fermentation engines)	TJ	969	1'122	1'403	1'593

Table 3-25 shows that in 2013, waste-derived fuels are the major component with 74% of the total fuel consumptions. All fossil fuels together have a share of 14% in total consumption, with natural gas dominating the fossil fuels. Biomass and biogas contribute 12% to the total fuel consumption. Please note in CRF tables biogenic fraction of waste is reported under biomass while in Table 3-25 it is split into the categories Other (waste-to-energy), biogenic and Biomass.

Overall, waste-derived fuels increased by 52% from 1990 to 2013. This is due to the fact that since 1st of January 2000, disposal of combustible wastes in landfill sites is prohibited by law (TVA Art. 32). The increase is also partly due to municipal solid waste imported from neighbouring countries to optimize the load factor of MSWIPs. The consumption of natural gas increased by 69% and the consumption of liquid fuels decreased by 17% for gas oil and 98% for residual fuel oil over the same period due to a fuel shift in combined heat and power generation and the closure of the only fossil fuel power station in the 1990ies.

Municipal solid waste incineration ("Other fuels")

Figure 7-4 in Sector 5 Waste gives an overview over the waste amounts, their treatment and their reporting in the Swiss greenhouse gas inventory. Municipal solid waste includes waste generated in households and waste of similar composition from other sources. Energy recovery from municipal solid waste incineration is mandatory in Switzerland, therefore all MSWIPs are equipped with energy recovery systems (Schwager 2005) and emissions are allocated to category 1A1a. Please note that the amount of municipal solid waste reported in Table 3-26 is the total amount of waste burned (it includes fossil and biogenic shares).

Energy recovery is also required for special waste incineration plants, therefore, these emissions are also allocated to category 1A1a. Special waste is composed of special wastes with high calorific value, wastewater and sludge with organic load, inorganic solids and dusts, inorganic sludge containing heavy metals, acids and alkalis, PCB-containing wastes, non-metallic shredder residues, contaminated soil, filter materials and chemicals residues and others.

The activity data for carbonate-based flue gas treatment are based on the quantities of carbonate applied annually in MSWIP (INFRAS 2015). Between 1990 and 2006 there was only one installation with flue gas treatment based on calcium carbonate. The application of calcium carbonate stopped in 2006. Since 2013, there is one MSWIP that applies sodium bicarbonate in its flue gas treatment.

Table 3-26 Activity data for 1A1a Other fuels: municipal solid waste and special waste incinerated with heat and/or power generation 1990 to 2013. Please note that the amount of municipal solid waste is the total amount of waste burned.

1A1a Public electricity and heat production, Other fuels	**Unit**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Total Other fuels in 1A1a	kt	2'603	2'477	2'467	2'441	2'411	2'433	2'471	2'535	2'655	2'824
Municipal solid waste	kt	2'470	2'340	2'310	2'310	2'250	2'270	2'290	2'337	2'419	2'586
Special waste	kt	133	137	157	131	161	163	181	198	237	238
Carbonate use in MSWIP	kt	0.71	0.71	0.71	0.71	0.42	0.76	0.72	0.82	0.83	0.53

1A1a Public electricity and heat production, Other fuels	**Unit**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Total Other fuels in 1A1a	kt	3'040	3'163	3'258	3'226	3'366	3'527	3'896	3'816	3'865	3'827
Municipal solid waste	kt	2'801	2'936	3'027	2'995	3'135	3'297	3'646	3'580	3'610	3'597
Special waste	kt	239	227	232	231	231	230	250	236	255	230
Carbonate use in MSWIP	kt	0.82	0.82	0.76	0.71	0.70	0.61	0.10	0	0	0

1A1a Public electricity and heat production, Other fuels	**Unit**	**2010**	**2011**	**2012**	**2013**
Total Other fuels in 1A1a	kt	3'968	3'924	4'104	3'912
Municipal solid waste	kt	3'717	3'676	3'841	3'650
Special waste	kt	252	247	263	262
Carbonate use in MSWIP	kt	0	0	0	2.72

Petroleum Refining (1A1b)

Methodology

For fuel combustion in Petroleum Refining (1A1b), a country-specific Tier 2 bottom-up method is used. The calculations are based on measurements and data from individual sources from the refining industry.

The emissions are calculated by multiplying the fuel consumption by the respective emission factor.

Emission Factors

The following Table 3-27 presents the emission factors used in 1A1b:

Table 3-27 Emission Factors for 1A1b Petroleum Refining in 2013.

1A1b Petroleum refining	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
	t/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ
Residual fuel oil	77	4	0.8	110	15	2.5	490
Refinery gas	59.8	1	0.6	55	15	2.3	25
Petroleum coke	91.4	10	0.6	200	100	10.0	500

Emission factors of residual fuel oil and petroleum coke are explained in section 3.2.4.2. The CO_2 emission factor of refinery gas is based on information on refinery gas composition over three successive years from one of the two refineries. The resulting CO_2 emission factor is higher than the IPCC default, but lies within the given range of 48.2 - 69.0 t/TJ (IPCC 2006).

Activity Data

Activity data on fuel combustion (TJ) for petroleum refining (1A1b) is taken from the annual reports of the Swiss Petroleum Association (EV 2014). Table 3-28 shows that refinery gas is the major fuel used in source category 1A1b with a contribution of 80% in 2013. Energy consumption, in particular use of refinery gas, has increased substantially since 1990 because one of the two Swiss refineries operated at reduced capacity in 1990 and resumed full production in later years. In 2012, one of the refineries was closed over six month due to insolvency and the search for a new buyer, which explains the lower fuel consumption in 2012 (EV 2014).

Table 3-28 Activity data for 1A1b Petroleum Refining.

1A1b Petroleum refining	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total	TJ	5'906	8'670	8'137	9'290	10'679	10'317	11'092	10'693	11'022	11'353
Residual fuel oil	TJ	1'296	1'216	998	1'054	1'426	1'834	1'618	1'780	1'428	1'698
Refinery gas	TJ	4'610	7'454	7'139	8'237	9'253	8'483	9'474	8'913	9'594	9'655
Petroleum coke	TJ	0	0	0	0	0	0	0	0	0	0

1A1b Petroleum refining	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total	TJ	10'091	10'909	11'447	10'525	14'257	14'395	15'814	13'482	14'841	14'200
Residual fuel oil	TJ	1'952	1'936	1'518	1'769	1'339	906	692	1'159	707	742
Refinery gas	TJ	8'139	8'973	9'929	8'756	11'901	11'678	13'311	10'766	11'687	11'424
Petroleum coke	TJ	0	0	0	0	1'017	1'811	1'811	1'557	2'447	2'034

1A1b Petroleum refining	Unit	2010	2011	2012	2013
Total	TJ	13'912	12'969	11'162	13'760
Residual fuel oil	TJ	895	776	1'228	1'067
Refinery gas	TJ	11'015	10'508	8'154	11'009
Petroleum coke	TJ	2'002	1'684	1'780	1'684

Manufacture of Solid Fuels and Other Energy Industries (1A1c)

Methodology

In source category 1A1c Manufacture of solid fuels and other energy industries, only the emissions from charcoal production are reported as no other activities occur in Switzerland.

A country-specific Tier 2 bottom-up method is used. Emissions from charcoal production are calculated by multiplying the annual amount of charcoal produced by the corresponding emission factors.

Emission Factors

The CO_2 emission factor is based on literature (USEPA 1995) and CH_4, NOx, CO and NMVOC emission factors are taken from Revised 1996 IPCC Guidelines, Reference Manual as documented in EMIS 2015/1A1c.

Table 3-29 Emission factors for 1A1c Manufacture of solid fuels and other energy industries in 2013. The CO_2 emission factor refers to CO_2 of biogenic origin.

1A1c Charcoal	Unit	CO_2 biog.	CH_4	NO_x	CO	NMVOC
Charcoal production	kg/TJ	16'900	1'000	10	7'000	1'700

Activity Data

The annual amount of charcoal produced is based on detailed queries with the few remaining sites where charcoal is produced. The main producer is the Köhlerverein Romoos, small quantities are produced at individual traditional local trade shows (Karthause Ittingen, Freilichtmuseum Ballenberg), as documented in EMIS 2015/1A1c. The FAO database contained values that differ substantially from these detailed bottom-up data. FAO has been informed about the discrepancy and was provided with the data used in the greenhouse gas inventory.

The charcoal is no more used in industry but mainly for barbecues. Production has increased by a factor of 1.9 between 1990 and 2013 due to two regular charcoal production sites starting operation in 2004, low wood prices and increased demand for local charcoal in Switzerland (Koehlerei, 2014).

Table 3-30 Activity data for 1A1c Manufacture of Solid Fuels and Other Energy Industries.

1A1c Charcoal	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Charcoal production	TJ	1.25	1.67	1.25	1.55	1.64	1.43	1.73	2.43	1.78	1.90

1A1c Charcoal	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Charcoal production	TJ	2.20	1.84	1.76	2.17	2.35	3.00	2.96	3.11	3.15	3.12

1A1c Charcoal	Unit	2010	2011	2012	2013
Charcoal production	TJ	2.82	2.93	3.25	2.45

3.2.5.3 Uncertainties and Time-Series Consistency

The uncertainty of CO_2 emission factors is described in section 3.2.4.4, the uncertainty in emissions of non-CO_2 gases are estimated to be medium, i.e. 30% for CH_4 and 80% for N_2O (see also chapter 1.7, Table 1-11).

Consistency: Time series for 1A1 Energy industries are all considered consistent.

3.2.5.4 Category-specific QA/QC and Verification

The general QA/QC procedures are described in section 1.2.3. Furthermore QA/QC procedures conducted for all 1A source categories are listed in 3.2.4.5

The fossil/biogenic split of municipal solid waste has been reassessed for submission 2015 (Rytec 2014). The study combined information regarding waste composition for 1992, 2002 and 2012 (FOEN 2014o) with ^{14}C measurements in the flue gas of different MSWIPs in 2010-2011 (Mohn 2011) to derive a consistent, calibrated time-series of fossil fraction of wastes in MSWIPs. In addition, also the carbon content of MSW was reassessed and is now based on an empirical relationship between calorific value and carbon content (FOEN 2014l).

Concerning activity data and emission factors in the refinery sector, collections of emissions and fuel combustion statistics at large combustion plants for pollution legislation purposes exist. This plant-level data was used to cross-check national energy statistics from this sector for representativeness.

3.2.5.5 Category-Specific Recalculations

- 1A: The entire emission factor model for 1A1a, 1A2f, 1A2gviii, 1A4ai, 1A4bi and 1A4ci Wood combustion has been revised for 1990-2012 resulting in revised values for CH_4, CO and NMVOC.
- 1A: For wood combustion, the previously used country-specific value of the N_2O EF (1.6 g/GJ) has been replaced by the default value of the 2006 IPCC Guidlines (4.0 g/GJ) for the entire time series, based on a recommendation from the ERT (UNFCCC 2014c).

- 1A: In 1A1a, 1A2f, 1A2gviii, 1A4ai, 1A4bi and 1A4ci Wood combustion the AD (wood) of automatic boilers (> 50 kW) have been revised for 1990-2012 due to recalculations in the Swiss wood energy statistics.
- 1A: Revised activity data for 1A1-1A5 for all years from 1990-2013 and all fuels due to a large-scale revision of the Swiss overall energy statistics.
- 1A: The default CO_2 emission factor for natural gas was replaced by a country-specific emission factor for the entire time period from 1990-2013.
- 1A: In earlier submissions, petroleum coke was reported together with coal, therefore, the N_2O emission factor for petroleum coke used was equal to the default emission factor for coal (1.6 g/GJ). As petroleum coke is reported separately, default emission factor for petroleum coke from the IPCC Guidelines 2006 is used (0.6 g/GJ).
- 1A1a: Municipal waste incineration: Carbon content of waste is now based on annual data of net calorific value. Previously, the carbon content was based on expert judgements. The revised carbon content is lower than before, consequently also the CO_2-EF is lower. In addition, the share of fossil carbon in waste has been reassessed in order to derive a consistent time series.
- 1A1a: Municipal waste incineration: an error in the calculation of the weighted averages (waste amounts) of the EF for N_2O has been corrected. This leads to different EF for all years except 1990.
- 1A1a: Values of the amounts of biogas used and fed into the gas system have changed for the years 2011 and 2012 in the Swiss renewable energy statistics. This leads to changes in activity data of industrial biogas facilities.
- 1A1a: The amount of digestate used by agricultural biogas facilities has been corrected due to a plausibility check based on detailed data provided by Ökostrom Switzerland and FOEN monitoring reports for CO_2 compensation projects. This leads to lower amounts of digestate.
- 1A1a: In source category 1A1a iv Municipal waste incineration plants, the CO_2 emissions from carbonate use for sulphur oxide removal are newly reported in the inventory for the years 1990-2006. There was only one plant using limestone for sulphur oxide removal.

3.2.5.6 Source-Specific Planned Improvements

For N_2O emission factors from waste incineration it is planned to calculate a new value in submission 2017 based on the amounts of waste burnt in 2015. See documentation in EMIS 2015/1A1a Kehricht- und Sondermüllverbrennungsanlagen.

3.2.6 Source Category 1A2 - Manufacturing industry and construction

3.2.6.1 Source Category Description

Approach 1 Key categories 1A2

CO_2 from the combustion of Liquid Fuels (level and trend)
CO_2 from the combustion of Solid Fuels (level and trend)
CO_2 from the combustion of Gaseous Fuels (level and trend)
CO_2 from the combustion of Other Fuels (level and trend)

Approach 2 Key categories 1A2

CO_2 from the combustion of Solid Fuels (level and trend)
CO_2 from the combustion of Gaseous Fuels (level and trend)
CO_2 from the combustion of Other Fuels (level and trend)

The source category 1A2 Manufacturing industries and construction comprises all emissions from the combustion of fuels in stationary boilers and cogeneration facilities within manufacturing industries and construction. This includes use of conventional fossil fuels as well as waste derived fuels and biomass. Use of fossil fuels as feedstocks or other non-energy use of fuels as for example bitumen and lubricants are reported in CRF-table 1.A(d) and described in section 3.2.3.

In addition, this source category includes emissions from non-road construction and industrial vehicles and machinery in source category 1A2gvii, such as for example forklifts, diggers or industry tractors (see also chapter 3.2.4.1.2.)

Table 3-31 Specification of source category 1A2 Manufacturing Industries and Construction. EMIS 2015/… refers to the internal documentation of the emission database and contains further references regarding specific AD and/or EF.

1A2	Source	Specification	Data Source
1A2a	Iron and steel	Iron and steel industry: boilers, cupola furnaces in iron foundries and heating furnaces in steel production	AD: SFOE 2014; SFOE 2014d; EMIS 2015/1A2a EF: SAEFL 2000 EMIS 2015/1A2a
1A2b	Non-ferrous metals	Non-ferrous metals industry: aluminium remelting, copper alloys production	AD: SFOE 2014; SFOE 2014d; EMIS 2015/1A2b EF: SAEFL 2000 EMIS 2015/1A2b
1A2c	Chemicals	Chemical industry: production of chemicals such as. ammonia, nitric acid, ethylene, acetic acid and sulphuric acid as well as silicon carbide (amongst others)	AD: SFOE 2014; SFOE 2014d; EMIS 2015/1A2c EF: SAEFL 2000 EMIS 2015/1A2c
1A2d	Pulp, paper and print	Pulp, paper and print industry, geogene emissions from carbonate use for fluegas purification	AD: SFOE 2014; SFOE 2014d; EMIS 2015/1A2d EF: SAEFL 2000 EMIS 2015/1A2d
1A2e	Food processing, beverages and tobacco	Food processing, beverages and tobacco industry: meat production, milk products, convenience food, chocolate, sugar and baby food (amongst others).	AD: SFOE 2014; SFOE 2014d; EF: SAEFL 2000
1A2f	Non-metallic minerals	Fine ceramics, container glass, glass, glass wool, lime, rock wool, mixed goods, cement, brick and tile	AD: Industry data EF: Industry data, EMIS 2015/solid fuels/wood, EMIS 2015/1A2f
1A2g	Other	Fibreboard production non-road construction and industrial vehicles and machinery, industrial fossil fuel and biomass boilers and engines that do not provide heat or electricity to the public.	AD, EF: INFRAS 2008, SFOE 2014; SFOE 2014a; SFOE 2014b; SFOE 2014c; SFOE 2014d EMIS 2015/1A Holzfeuerungen AD (partial update): SFOE 2012, Keller/INFRAS 2014

3.2.6.2 Methodological Issues

Methodology

For fuel combustion in source category 1A2 Manufacturing industries and construction, a country-specific approach, as explained in chapter 3.2.4.1.2 is used combining Tier 2 and Tier 3 methods.

Emissions of GHGs are calculated by multiplying the level of activity (fuel consumption) by the respective emission factors.

Within 1A2g, also emissions from diesel and gasoline use in construction and industrial non-road machinery (1A2gvii) is included and accounted for (see also 3.2.4.1.2). They are calculated with a Tier 2 method. Some details of the emission modelling that hold for all non-road families are described in Annex A3.1.4 Non-road vehicles. Emission calculation was carried out in a database structured in analogy to the on-road database (INFRAS 2008).

Emission factors

The following Table 3-32 presents the emission factors used in source category 1A2 Manufacturing industry and construction. Emission factors in Table 3-32 concerning the main fuels (e.g. Gas oil) are explained in section 3.2.4.2 while emission factors shaded in grey are implied emission factors.

Table 3-32 Emission Factors for 1A2 Manufacturing Industries and Construction in 2013. Values shaded in grey are implied emission factors.

1A2 Emission factors (mix of bottom-up and top-down approach (modelling)) for GHG	**CO_2 fossil**	**CO_2 bio.**	**CH_4**	**N_2O**
	t/TJ	t/TJ	kg/TJ	kg/TJ
Gas oil	73.7		1.0	0.6
Liquefied petroleum gas	65.5		1.0	0.6
Residual fuel oil	77.0		3.6	0.8
Petroleum coke	91.4		2.2	0.6
Other bituminous coal	92.7		1.7	1.6
Lignite	96.1		0.6	1.6
Natural gas	56.4		6.0	0.1
Biomass		85.1	6.4	3.2
Other fossil fuels	69.1		3.6	3.6
Diesel and gasoline for construction and industrial machinery	73.3		2.2	2.9

Other fuels comprises various fossil waste derived fuels used in cement production within source category 1A2f Non-metallic minerals. The CO_2 emission factor of this type of fuel is an implied emission factor based on the fossil waste fuel mix in cement production plants. The CH_4 emission factor includes the total CH_4 emissions of the cement industry based on direct exhaust measurements at the chimneys of the cement plants (see documentation in EMIS 2015/1A2fi Zementwerke_Feuerung based on industry data measurements and emission declarations according to the Ordinance on Air Pollution Control for 2002. CH_4 emission factors for residual fuel oil, petroleum coke, other bituminous coal and lignite are lower than the emission factors explained in section 3.2.4.2 (see detailed description below in section Cement (1A2f i)).

The emission factors of the precursors NO_x, CO, NMVOC and SO_2 for all fuels in source category 1A2 are provided in Annex A3.1.3. For NOx emission factors, expert judgement has been used to estimate the fraction of low-NOx burners. The emission factors for NOx and CO for natural gas and gas oil have been recalculated for the submission 2013 for the time series based on a new study (Leupro 2012). This study analyses a large pool of primary data from various cantons in Switzerland that was collected over the years between 2000 and 2011. The implied emission factors for NOx decreased significantly and are expected to further decrease due to improvements in waste incineration technology. NMVOC and SO_2 emission factors are country-specific and based on measurements as documented in the respective EMIS documentation.

For non-road activities (1A2gvii), the CO_2 emission factors diesel oil, gasoline and compressed natural gas are country-specific, as presented in chapter 3.2.4.2). The emission factors for all other gases are country-specific and shown in Table A - 18 to Table A - 26 in the Annex A3.1.4 (INFRAS 2008). NMVOC emissions are calculated as the difference of

VOC and CH_4 emissions. Note that specific emission factors in the unit of kg/h may be downloaded by query from the public part of the non-road database INFRAS (2008). For non-road activities SO_2 emission factors are country-specific and further described in Table A – 29 in Annex 3.1.5.

Activity Data

Table 3-31 provides the time series of all fuels consumed in source category 1A2 Manufacturing industry and construction. Activity data of the individual source categories differentiated by fuel type are determined as described in chapter 3.2.4.1.2. For the stationary fuel consumption the data are based on the Swiss overall energy statistics (SFOE 2014), Helbling statistics (SFOE 2014d), Prognos industry model (Prognos 2012a) and bottom-up industry data. Further, specific statistical data (SFOE 2014a, SFOE 2014b and SFOE 2014c) are considered in source category 1A2gviii only. Activity for non-road (1A2gvii) is modelled as described in 3.2.4.1.2. and in more detail in 3.2.7.2.

As displayed in the following Table 3-33 source category 1A2g Other comprising also emissions from boilers and engines is the most important category within source category 1A2 Manufacturing Industries and Construction and accounted for 43% of the overall fuel consumption in 2013. Categories 1A2f Non-metallic minerals and 1A2c Chemicals are the second and third most important fuel consumers with 17% and 15% respectively.

Regarding the fuels used within Swiss industry, natural gas consumption represents 42% of fuel consumption in 2013 followed by gas oil and biomass with shares of 19% and 15%, respectively.

The table also documents the fuel switch within Swiss industry. From 1990 to 2013 the use of residual fuel oil and other bituminous coal has decreased by 96% and 68%, respectively. In the same period, natural gas consumption has more than doubled.

Table 3-33 Activity data fuel consumption in 1A2 Manufacturing industries and construction 1990 to 2013.

Source	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1A2 Manufacturing industries and constr. (Total)	TJ	97'041	102'932	98'835	97'752	97'206	100'665	100'100	99'570	102'799	101'558
Gas oil	TJ	21'766	27'031	26'158	24'631	22'388	23'536	24'859	26'392	27'626	26'860
Liquefied petroleum gas	TJ	4'520	5'353	4'730	4'568	4'669	4'706	4'969	5'772	6'151	6'651
Residual fuel oil	TJ	18'870	17'386	16'851	14'379	14'914	13'678	11'083	9'764	10'382	8'174
Petroleum coke	TJ	1'271	890	286	1'017	1'335	1'144	922	254	413	477
Other bituminous coal	TJ	12'151	10'376	7'018	5'886	5'961	6'592	4'959	3'828	3'221	3'293
Lignite	TJ	306	353	306	259	259	188	236	165	141	141
Natural gas	TJ	18'843	21'532	22'975	25'573	26'160	28'082	28'618	29'239	29'905	30'660
Biomass	TJ	6'628	6'915	7'006	7'166	7'359	7'832	9'059	8'594	8'707	9'015
Other Fuels	TJ	7'175	7'394	7'614	8'194	7'892	8'447	8'816	8'860	9'429	9'343
Gasoline	TJ	179	184	189	195	200	205	206	207	208	209
Diesel	TJ	5'333	5'517	5'701	5'885	6'069	6'252	6'373	6'494	6'615	6'736
1A2a Iron and steel	TJ	3'310	4'020	3'415	4'239	3'280	2'570	2'516	2'709	2'911	3'245
Gas oil	TJ	480	498	523	475	428	262	261	304	314	368
Liquefied petroleum gas	TJ	408	434	386	345	341	193	196	241	272	310
Residual fuel oil	TJ	346	350	364	370	367	131	128	139	151	7
Petroleum coke	TJ	0	0	0	0	0	0	0	0	0	0
Other bituminous coal	TJ	433	347	328	259	263	289	247	253	273	271
Lignite	TJ	0	0	0	0	0	0	0	0	0	0
Natural gas	TJ	1'643	2'392	1'812	2'790	1'881	1'695	1'683	1'771	1'900	2'289
1A2b Non-ferrous metals	TJ	2'379	2'394	2'039	1'701	1'571	1'969	1'678	2'187	1'865	1'419
Gas oil	TJ	587	610	393	351	301	347	289	311	302	232
Liquefied petroleum gas	TJ	27	28	22	15	15	17	15	23	20	16
Residual fuel oil	TJ	0	0	0	0	0	0	0	0	0	0
Petroleum coke	TJ	0	0	0	0	0	0	0	0	0	0
Other bituminous coal	TJ	0	0	0	0	0	0	0	0	0	0
Lignite	TJ	0	0	0	0	0	0	0	0	0	0
Natural gas	TJ	1'765	1'757	1'624	1'334	1'255	1'605	1'374	1'853	1'543	1'172
1A2c Chemicals	TJ	14'436	14'538	13'509	13'024	13'604	15'158	15'156	14'002	14'266	13'622
Gas oil	TJ	3'942	3'737	2'889	2'971	2'688	3'313	3'354	2'854	2'492	3'797
Liquefied petroleum gas	TJ	15	16	14	11	13	13	13	14	16	13
Residual fuel oil	TJ	1'434	1'193	851	796	654	693	561	383	256	315
Petroleum coke	TJ	0	0	0	0	0	0	0	0	0	0
Other bituminous coal	TJ	0	0	0	0	0	0	0	0	0	0
Lignite	TJ	0	0	0	0	0	0	0	0	0	0
Natural gas	TJ	9'044	9'593	9'755	9'246	10'249	11'138	11'228	10'751	11'502	9'496
1A2d Pulp, paper and print	TJ	11'762	12'413	13'856	14'183	15'008	13'700	12'918	13'177	13'010	12'657
Gas oil	TJ	1'188	1'594	1'644	1'674	1'607	1'751	1'959	2'130	2'275	1'722
Liquefied petroleum gas	TJ	86	110	150	148	180	141	127	144	144	149
Residual fuel oil	TJ	5'250	4'904	4'136	3'667	3'228	3'061	2'867	2'885	2'739	2'027
Petroleum coke	TJ	0	0	0	0	0	0	0	0	0	0
Other bituminous coal	TJ	0	0	0	0	0	0	0	0	0	0
Lignite	TJ	0	0	0	0	0	0	0	0	0	0
Natural gas	TJ	3'153	3'906	6'215	7'170	8'552	7'389	6'523	6'493	6'242	7'065
Biomass	TJ	2'085	1'898	1'711	1'524	1'441	1'358	1'442	1'526	1'610	1'694
1A2e Food processing, beverages and tobacco	TJ	9'859	11'753	11'163	11'032	8'951	8'784	10'985	10'234	10'149	10'043
Gas oil	TJ	7'410	9'153	8'537	8'149	6'013	5'511	7'414	6'750	6'479	5'500
Liquefied petroleum gas	TJ	204	260	252	257	287	308	353	410	462	554
Residual fuel oil	TJ	1'160	1'009	810	705	553	466	405	284	221	185
Petroleum coke	TJ	0	0	0	0	0	0	0	0	0	0
Other bituminous coal	TJ	0	0	0	0	0	0	0	0	0	0
Lignite	TJ	0	0	0	0	0	0	0	0	0	0
Natural gas	TJ	1'085	1'331	1'565	1'921	2'098	2'500	2'813	2'791	2'988	3'805
1A2f Non-metallic minerals	TJ	23'785	21'589	20'040	18'419	19'725	18'774	16'837	16'120	15'711	15'781
Gas oil	TJ	1'871	1'771	1'785	1'677	1'648	1'629	1'609	1'558	1'539	1'635
Liquefied petroleum gas	TJ	492	492	490	490	487	484	488	490	493	498
Residual fuel oil	TJ	5'375	6'299	7'467	6'249	7'499	5'586	6'002	5'557	5'361	5'360
Petroleum coke	TJ	1'124	862	255	724	1'051	830	550	240	410	466
Other bituminous coal	TJ	10'973	8'489	6'344	5'200	5'205	5'711	3'217	3'422	2'938	2'873
Lignite	TJ	306	353	306	259	259	188	236	165	139	136
Natural gas	TJ	1'769	1'423	1'465	1'441	1'433	1'566	1'414	1'431	1'461	1'584
Biomass	TJ	33	23	14	70	318	585	878	893	557	622
Other Fuels	TJ	1'841	1'877	1'913	2'310	1'823	2'195	2'443	2'366	2'814	2'607
1A2g Other	TJ	26'177	30'706	29'112	29'269	28'998	33'458	33'638	34'645	38'271	38'055
Gas oil	TJ	6'288	9'668	10'388	9'333	9'702	10'723	9'974	12'487	14'224	13'607
Liquefied petroleum gas	TJ	3'287	4'013	3'415	3'302	3'347	3'550	3'777	4'450	4'743	5'111
Residual fuel oil	TJ	5'305	3'632	3'223	2'592	2'613	3'741	1'119	516	1'654	279
Petroleum coke	TJ	147	28	31	293	284	314	372	14	3	11
Other bituminous coal	TJ	744	1'540	345	427	492	592	1'495	153	10	149
Lignite	TJ	0	0	0	0	0	0	0	0	3	5
Natural gas	TJ	384	1'130	539	1'670	691	2'189	3'582	4'149	4'270	5'251
Biomass	TJ	4'510	4'993	5'280	5'572	5'600	5'889	6'739	6'175	6'540	6'698
Gasoline	TJ	179	184	189	195	200	205	206	207	208	209
Diesel	TJ	5'333	5'517	5'701	5'885	6'069	6'252	6'373	6'494	6'615	6'736

Table continued: Activity data fuel consumption in 1A2 Manufacturing industries and construction.

Source	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1A2 Manufacturing industries and constr. (Total)	TJ	93'666	98'492	93'001	95'683	97'934	98'405	101'280	99'401	100'443	95'102
Gas oil	TJ	25'150	26'281	24'204	25'147	24'485	24'713	23'545	21'608	21'391	21'009
Liquefied petroleum gas	TJ	5'921	5'559	6'154	5'316	5'159	4'599	5'070	4'554	4'310	4'595
Residual fuel oil	TJ	5'675	7'644	4'564	4'875	5'891	4'613	5'427	3'776	3'734	2'713
Petroleum coke	TJ	508	381	636	191	763	1'049	1'462	1'239	1'049	1'208
Other bituminous coal	TJ	5'264	5'435	4'827	5'191	4'667	4'667	4'030	4'819	4'361	4'208
Lignite	TJ	141	71	94	94	94	801	2'026	2'003	1'767	1'555
Natural gas	TJ	31'629	32'547	30'883	32'266	33'493	34'621	36'092	37'164	38'976	35'385
Biomass	TJ	9'313	10'479	11'144	12'046	12'297	12'162	12'489	13'108	13'141	12'480
Other Fuels	TJ	2'998	2'993	3'354	3'380	3'872	3'931	3'814	3'727	4'237	4'394
Gasoline	TJ	209	208	206	204	202	200	201	201	201	202
Diesel	TJ	6'857	6'896	6'934	6'973	7'012	7'050	7'126	7'201	7'277	7'353
1A2a Iron and steel	TJ	3'351	3'387	3'596	3'822	3'648	3'389	4'208	4'415	4'156	3'190
Gas oil	TJ	338	400	381	420	391	401	311	326	307	279
Liquefied petroleum gas	TJ	286	263	339	299	270	217	313	295	246	214
Residual fuel oil	TJ	20	40	3	1	52	39	52	36	51	39
Petroleum coke	TJ	0	0	0	0	0	0	0	0	0	0
Other bituminous coal	TJ	266	234	179	163	148	154	150	160	177	70
Lignite	TJ	0	0	0	0	0	0	0	0	0	0
Natural gas	TJ	2'440	2'449	2'695	2'939	2'788	2'578	3'382	3'598	3'374	2'588
1A2b Non-ferrous metals	TJ	1'560	1'440	736	958	1'153	977	1'162	1'022	1'042	1'006
Gas oil	TJ	236	88	147	130	87	125	72	94	112	167
Liquefied petroleum gas	TJ	15	14	7	8	10	7	10	8	7	7
Residual fuel oil	TJ	0	0	39	0	0	0	0	0	0	0
Petroleum coke	TJ	0	0	0	0	0	0	0	0	0	0
Other bituminous coal	TJ	0	0	0	0	0	0	0	0	0	0
Lignite	TJ	0	0	0	0	0	0	0	0	0	0
Natural gas	TJ	1'309	1'338	542	819	1'056	845	1'080	920	924	833
1A2c Chemicals	TJ	13'500	14'055	12'530	13'864	14'179	15'477	14'995	14'810	14'610	12'611
Gas oil	TJ	3'215	3'014	2'710	3'171	3'206	3'345	3'210	2'556	2'261	2'498
Liquefied petroleum gas	TJ	12	12	13	12	11	10	11	10	9	9
Residual fuel oil	TJ	252	281	83	84	88	36	71	6	79	91
Petroleum coke	TJ	0	0	0	0	0	0	0	0	0	0
Other bituminous coal	TJ	0	0	0	0	0	0	0	0	0	0
Lignite	TJ	0	0	0	0	0	0	0	0	0	0
Natural gas	TJ	10'020	10'747	9'725	10'598	10'875	12'086	11'704	12'239	12'261	10'014
1A2d Pulp, paper and print	TJ	11'580	12'784	12'114	12'583	12'460	11'379	11'493	10'236	9'455	5'974
Gas oil	TJ	1'403	1'546	1'477	1'605	1'336	1'456	1'291	1'096	1'019	948
Liquefied petroleum gas	TJ	148	141	171	138	109	100	79	71	60	62
Residual fuel oil	TJ	1'417	2'250	1'507	2'436	2'719	2'092	3'305	1'885	1'887	934
Petroleum coke	TJ	0	0	0	0	0	0	0	0	0	0
Other bituminous coal	TJ	0	0	0	0	0	0	0	0	0	0
Lignite	TJ	0	0	0	0	0	0	0	0	0	0
Natural gas	TJ	6'918	7'400	7'218	6'519	6'268	5'678	4'742	5'085	5'164	4'030
Biomass	TJ	1'694	1'447	1'741	1'885	2'029	2'053	2'076	2'099	1'324	0
1A2e Food processing, beverages and tobacco	TJ	10'439	10'643	10'147	9'904	9'921	10'239	11'519	11'221	10'975	12'558
Gas oil	TJ	5'515	5'480	4'822	4'586	4'323	4'070	3'811	3'500	3'376	3'687
Liquefied petroleum gas	TJ	535	520	623	543	545	534	678	596	535	736
Residual fuel oil	TJ	137	140	31	25	28	0	0	0	0	0
Petroleum coke	TJ	0	0	0	0	0	0	0	0	0	0
Other bituminous coal	TJ	0	0	0	0	0	0	0	0	0	0
Lignite	TJ	0	0	0	0	0	0	0	0	0	0
Natural gas	TJ	4'251	4'503	4'671	4'750	5'026	5'635	7'031	7'126	7'064	8'135
1A2f Non-metallic minerals	TJ	16'596	16'983	16'032	15'683	16'881	17'239	17'286	17'535	17'160	16'525
Gas oil	TJ	1'642	1'540	1'512	1'504	1'549	1'388	1'482	1'343	1'298	1'260
Liquefied petroleum gas	TJ	503	494	455	446	336	329	225	181	160	95
Residual fuel oil	TJ	3'649	3'434	2'853	2'276	2'480	2'420	1'704	1'744	1'598	1'374
Petroleum coke	TJ	458	327	590	187	515	638	903	912	1'036	994
Other bituminous coal	TJ	4'989	5'194	4'235	4'577	4'347	4'364	3'661	4'348	3'912	3'940
Lignite	TJ	136	71	94	94	94	737	1'834	1'790	1'596	1'379
Natural gas	TJ	1'496	1'363	1'215	1'268	1'714	1'861	2'057	2'017	1'919	1'731
Biomass	TJ	726	1'567	1'723	1'952	1'974	1'572	1'607	1'473	1'403	1'358
Other Fuels	TJ	2'998	2'993	3'354	3'380	3'872	3'931	3'814	3'727	4'237	4'394
1A2g Other	TJ	29'784	32'305	30'911	31'896	32'680	32'654	33'490	32'960	35'768	35'884
Gas oil	TJ	12'801	14'213	13'153	13'731	13'595	13'928	13'368	12'695	13'018	12'171
Liquefied petroleum gas	TJ	4'422	4'114	4'548	3'870	3'878	3'402	3'754	3'392	3'293	3'473
Residual fuel oil	TJ	199	1'498	48	53	526	26	295	105	119	274
Petroleum coke	TJ	50	54	46	4	247	411	559	328	13	213
Other bituminous coal	TJ	9	6	413	451	172	148	219	312	272	198
Lignite	TJ	5	0	0	0	0	64	192	212	171	176
Natural gas	TJ	5'195	4'747	4'818	5'374	5'766	5'938	6'096	6'180	8'269	8'055
Biomass	TJ	6'893	7'465	7'680	8'210	8'294	8'537	8'807	9'536	10'414	11'122
Gasoline	TJ	209	208	206	204	202	200	201	201	201	202
Diesel	TJ	6'857	6'896	6'934	6'973	7'012	7'050	7'126	7'201	7'277	7'353

Table continued: Activity data fuel consumption in 1A2 Manufacturing industries and construction.

Source	Unit	2010	2011	2012	2013
1A2 Manufacturing industries and constr. (Total)	TJ	97'869	91'367	92'517	94'661
Gas oil	TJ	20'691	16'775	17'161	17'788
Liquefied petroleum gas	TJ	4'181	4'136	3'998	4'002
Residual fuel oil	TJ	2'096	1'518	1'568	848
Petroleum coke	TJ	1'494	1'271	1'367	1'049
Other bituminous coal	TJ	4'336	3'826	3'674	3'877
Lignite	TJ	1'461	1'626	1'178	1'366
Natural gas	TJ	38'304	37'166	38'296	39'919
Biomass	TJ	13'097	12'820	13'589	13'838
Other Fuels	TJ	4'580	4'685	4'225	4'599
Gasoline	TJ	202	199	197	194
Diesel	TJ	7'428	7'346	7'263	7'181
1A2a Iron and steel	TJ	3'773	3'805	3'636	3'497
Gas oil	TJ	315	271	172	148
Liquefied petroleum gas	TJ	219	226	438	438
Residual fuel oil	TJ	51	2	0	0
Petroleum coke	TJ	0	0	0	0
Other bituminous coal	TJ	64	73	55	55
Lignite	TJ	0	0	0	0
Natural gas	TJ	3'125	3'233	2'971	2'857
1A2b Non-ferrous metals	TJ	1'218	1'177	1'747	1'624
Gas oil	TJ	112	76	153	127
Liquefied petroleum gas	TJ	8	8	11	11
Residual fuel oil	TJ	0	0	1	23
Petroleum coke	TJ	0	0	0	0
Other bituminous coal	TJ	0	0	0	0
Lignite	TJ	0	0	0	0
Natural gas	TJ	1'098	1'093	1'582	1'462
1A2c Chemicals	TJ	11'814	12'167	13'915	13'901
Gas oil	TJ	2'103	1'847	2'055	1'745
Liquefied petroleum gas	TJ	8	7	10	10
Residual fuel oil	TJ	66	0	0	1
Petroleum coke	TJ	0	0	0	0
Other bituminous coal	TJ	0	0	0	0
Lignite	TJ	0	0	0	0
Natural gas	TJ	9'637	10'312	11'851	12'145
1A2d Pulp, paper and print	TJ	6'773	6'051	5'376	5'584
Gas oil	TJ	852	561	623	714
Liquefied petroleum gas	TJ	61	62	67	67
Residual fuel oil	TJ	279	4	3	0
Petroleum coke	TJ	0	0	0	0
Other bituminous coal	TJ	0	0	0	0
Lignite	TJ	0	0	0	0
Natural gas	TJ	5'581	5'424	4'684	4'803
Biomass	TJ	0	0	0	0
1A2e Food processing, beverages and tobacco	TJ	13'161	11'374	11'314	12'593
Gas oil	TJ	3'778	3'197	3'237	3'548
Liquefied petroleum gas	TJ	659	675	935	935
Residual fuel oil	TJ	0	0	0	0
Petroleum coke	TJ	0	0	0	0
Other bituminous coal	TJ	0	0	0	0
Lignite	TJ	0	0	0	0
Natural gas	TJ	8'723	7'502	7'142	8'110
1A2f Non-metallic minerals	TJ	17'580	17'146	16'276	16'518
Gas oil	TJ	1'269	1'238	1'097	1'174
Liquefied petroleum gas	TJ	102	127	108	113
Residual fuel oil	TJ	1'519	1'403	1'456	801
Petroleum coke	TJ	1'130	1'081	920	815
Other bituminous coal	TJ	3'992	3'474	3'403	3'478
Lignite	TJ	1'348	1'493	1'081	1'283
Natural gas	TJ	2'048	1'938	2'085	2'497
Biomass	TJ	1'592	1'706	1'900	1'759
Other Fuels	TJ	4'580	4'685	4'225	4'599
1A2g Other	TJ	43'550	39'648	40'252	40'944
Gas oil	TJ	12'262	9'585	9'825	10'331
Liquefied petroleum gas	TJ	3'124	3'031	2'428	2'427
Residual fuel oil	TJ	182	109	109	22
Petroleum coke	TJ	364	190	446	234
Other bituminous coal	TJ	280	279	215	344
Lignite	TJ	112	132	97	84
Natural gas	TJ	8'090	7'663	7'982	8'046
Biomass	TJ	11'506	11'113	11'690	12'080
Gasoline	TJ	202	199	197	194
Diesel	TJ	7'428	7'346	7'263	7'181

The following sections describe the different source categories of 1A2 Manufacturing industry and construction. Further information is documented in the respective EMIS documentation (EMIS 2015/1A2a-g).

Iron and steel (1A2a)

There is no primary iron and steel production in Switzerland. Only secondary steel and iron production using recycled steel scrap occurs.

Iron is produced in 14 iron foundries. About 75% of the iron is processed in induction furnaces and 25% in cupola furnaces. The share of induction furnaces increased since 1990 from 47% with a sharp increase in 2009 based on the closure of at least one cupola furnace. Induction furnaces use electricity for the melting process and therefore only process emissions occur, which are reported in source category 2C1 Iron and steel production. The use of other bituminous coal decreased significantly from 433 TJ in 1990 to 54.8 TJ in 2013. This is due to the significant decrease of iron founding between 1990 and 2013 and the switch from cupola furnaces to induction furnaces. Iron foundries add other bituminous coal in the production process to increase the carbon content of the raw material steel scrap to produce iron alloys with higher carbon content.

Today, steel is produced in two steel production plants. Both plants use electric arc furnaces (EAF) with carbon electrodes for melting the steel scrap. Therefore only emissions from the heating furnaces are included in source category 1A2a. These furnaces use mainly natural gas for reheating the ingot moulds prior to the rolling mills. Process emissions from steel production are included in source category 2C1 Iron and steel production. Steel production and the related natural gas consumption was significantly reduced in 1995 with the closure of two steel companies. Since 1995, steel production increased continuously until 2004 to reach the same production level as 1990. Since then, steel production is about constant. Only in 2009, the production was considerably lower based on economic crisis. One steel producer switched its production to high quality steel and therefore the specific energy use per tonne of steel produced increased between 1995 and 2000. This led to a higher natural gas consumption.

According to Table 3-33 fuel consumption of source category 1A2a represents 4% of overall industry fuel consumption in 2013. As displayed in Table 3-33, natural gas (82%), liquefied petroleum gas (13%), gas oil (4%) and other bituminous coal (2%) are used in source category 1A2a.

Between 1990 and 2013 the fuel consumption increased within this source category by 6%. Nevertheless, there has been a major change in the fuels used in the processes. The consumption of other bituminous coal decreased by 87% based on the reduced iron production and the switch from cupola to induction furnaces in iron foundries. Gas oil consumption also decreased by 69% whereas natural gas consumption increased by 74% partly due to the above mentioned switch to high quality steel production in one production plant. All these changes in fuel consumption result in an increase of GHG emissions which is significantly smaller than the fuel consumption increase.

Non-ferrous metals (1A2b)

The source category 1A2b Non-ferrous metals is based on specific information from the industry as well as information from the Prognos model and includes aluminium remelting plants as well as non-ferrous metal foundries, producing mainly copper alloys.

Until 1993, aluminium remelting plants have been in operation using gas oil. Emissions from primary aluminium production in Switzerland are reported in source category 2C3 as induction furnaces have been used. Its last production site closed down in April 2006.

Regarding non-ferrous metal industry in Switzerland, only casting and no production of non-ferrous metals occur. There is one large company and several small foundries which are organized within the Swiss foundries association (Schweizerischer Giessereiverband GVS) which both provide annual production data

Fuel consumption of source category 1A2b represents only 2% of the overall industry fuel consumption in 2013. As shown in Table 3-33, the fuels consumed in 2013 are mainly natural gas (90%), gas oil (8%), residual fuel oil (1%) and liquefied petroleum gas (1%). Fuel consumption within this source category decreased by 32% from 1990 to 2013. This is due to the closing down of the aluminium remelting plants and the strong reduction of the non-ferrous metal production since 2000. In the same time the consumption of gas oil and liquid petroleum gas decreased by 46% and 28%, respectively. The consumption of natural gas increased by 12%.

Chemicals (1A2c)

In Switzerland, there are more than thirty chemical companies mainly producing fine chemicals and pharmaceuticals. Fossil fuels are mostly used for steam production and process heat. The process emissions from the production of chemicals such as ammonia, nitric acid, ethylene, acetic acid and sulphuric acid as well as silicon carbide are reported in source category 2B, see Section 4.3.

There is one large company producing ammonia and ethylene by thermal cracking of liquefied petroleum gas and light virgin naphtha. As by-products from the cracking process, so-called heating gas and gasolio are produced which are used thermally for steam production within the same plant and are accounted for within source category 1A2c (see also descriptions in section 3.2.3).

Fuel consumption within 1A2c accounts for 15% of the overall industry fuel consumption in 2013. The fuels consumed in 2013 include natural gas (87%) and gas oil (13%) (Table 3-33). Fuel consumption in this source category has decreased by 4% between 1990 and 2013. Also a fuel switch becomes evident: gas oil, residual fuel oil and liquefied petroleum gas have decreased by 56%, 100% and 34% respectively in that period, while natural gas consumption on the other hand increased by 34%.

Pulp, paper and print (1A2d)

Around half a dozen paper producers and several printing facilities exist in Switzerland. The only cellulose production plant was closed in 2008. Thermal energy is mainly used for provision of steam used in the drying process within paper production. Furthermore geogenic CO_2 emissions result from carbonate use for fluegas purification for sulphur oxide removal as newly reported in the inventory.

Table 3-34 Activity data for limestone use in 1A2d Pulp, paper and print.

1A2d Pulp, paper and print	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Limestone use	Gg	8'500	8'700	8'900	9'100	9'200	9'400	9'500	9'500	9'600	9'500

1A2d Pulp, paper and print	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Limestone use	Gg	9'300	8'800	8'600	9'400	8'500	8'300	8'000	7'800	6'500	0

1A2d Pulp, paper and print	Unit	2010	2011	2012	2013
Limestone use	Gg	0	0	0	0

Source category 1A2d represents 6% of the overall fuel consumption in source category 1A2 in 2013. The fuels used in 2013 are mainly natural gas (86%) and gas oil (13%) (see Table 3-33). In this category only biomass from cellulose production (until 2008) is included, based on data from the only production site. Biomass used in paper production is reported in source category 1A2gviii, because no comprehensive information exists to distribute biomass consumption to the specific industry sectors within 1A2 as explained in Section 3.2.4.3.

The overall fuel consumption within the Swiss pulp and paper industry has decreased since 1990 by approximately 53%, basically due to the closure of the cellulose production plant in 2008 and of several paper producers in the last years. Since 1990 liquid fuels such as residual fuel oil, liquefied petroleum gas and gas oil have decreased by 100%, 22% and 40%, respectively. In the same time, natural gas consumption increased by 52%. Biomass consumption decreased by 100% as the cellulose production was shut down in 2008.

Food processing, beverages and tobacco (1A2e)

In Switzerland, the source category 1A2e Food, beverages and tobacco includes around 200 companies. According to the national food industry association, the major part of revenues is provided by meat production (22%), milk products (18%) and convenience food (13%). Further productions are chocolate, sugar or baby food (Fial 2013). Fossil fuels are used for steam production and drying processes.

Source category 1A2e accounts for 13% of the overall fuel consumption in source category 1A2 Manufacturing Industries and Construction in 2013. The fuels used in this category in the year 2013 were mainly natural gas (64%), gas oil (28%) and liquefied petroleum gas (7%) (see Table 3-33).

Source category 1A2e shows an increase in fuel consumption of 28% between 1990 and 2013. This is based on the increased production of this sector in Switzerland. The consumption of residual fuel oil and gas oil have decreased by 100% and 52% respectively, whereas liquefied petroleum gas consumption increased by a factor 3.6 and natural gas consumption by a factor 6.5.

Non-metallic minerals (1A2f)

The source category 1A2f Non-metallic minerals is based solely on specific bottom-up information from the industry. The source category includes several large fuel consumers within mineral industry, i.e. cement, brick and tile, glass and rock wool production. This source category accounts for 17% of the overall fuel consumption in 1A2 Manufacturing Industries and Construction in 2013.

Fuel consumption in 2013 comprises mainly other fossil fuels (28%), other bituminous coal (21%), natural gas (15%) and biomass (11%) (see Table 3-33).

The fuels consumed in this source category are very diverse, depending on the fuel use within the specific industry process (see detailed documentation below). Between 1990 and 2013 there has been a switch in fuel consumption from residual fuel oil with share 23% in 1990 to other fuels, biomass and natural gas (Table 3-33). Also the use of bituminous coal is very relevant (although its use is decreasing) while use of lignite has more than quadrupled in that period. Accordingly the consumption of residual fuel oil, liquefied petroleum gas, other bituminous coal and gas oil decreased by 85%, 77%, 68% and 37% respectively. Lignite consumption increased by 319%. Natural gas and other fuels consumption increased by 41% and 150% respectively. Specific industry developments and information on fuel use are described in the following sub chapters.

The most important industry within this category is cement production with approximately 71% of the total fuel consumption in 1A2f.

Cement

In Switzerland, there are six plants producing clinker and cement. The Swiss plants are rather small and do not exceed a production capacity of 3’000 tonnes of clinker per day. All of them use modern dry process technology. Cement industry emissions stem from incineration of a wide variety of fossil and waste derived fuels used to generate high temperatures needed for the calcination process.

Emission factors specific for the cement industry

For the first time in this submission emission factors for cement production (furnace) are related to tons of clinker, and not cement as it was before.

Table 3-35 Emission factors for cement industry in 2013. Source: EMIS data base (EMIS 2015/1A2f). Emission factors for CO_2 are fuel specific (see Table 3-33).

Cement industry (part of 1A2f)	**CO_2**	**N_2O**	**CH_4**	**NO_x**	**CO**	**NMVOC**	**SO_2**
	t/TJ		g/t clinker				
Cement	fuel specific		5	930	1'700	54.93	411

The CH_4 emission factor includes the overall CH_4 emissions of the cement industry based on direct exhaust measurements at the chimneys of the cement plants. Therefore these CH_4 emissions are reported under the fuel type other fossil fuels in the CRF-tables. For N_2O an implied emission factor is applied that changes on annual basis.

Table 3-36 CO_2 Emission factors and other characteristics of waste derived fuels (Other fuels and Biomass) used in the cement industry.

Cement industry (part of 1A2f)	**NCV**	**EF CO_2 Tot.**	**Fraction biomass-C**
Waste derived fuel	MJ/kg	kg CO_2/GJ	%
Waste oil	32.48	74.35	0
Waste coke from coke filters	23.70	97.00	0
Mixed industrial waste	18.34	74.00	0
Other fossil waste fuels	20.85	97.00	0
Solvents and residues from distillation	23.63	73.99	0.9
Waste tyres and rubber	26.40	84.00	27
Plastics	25.24	84.66	27.7
Mix of special waste with saw dust (CSS)	9.22	102.40	78.5
Sewage sludge (dried)	9.39	94.52	100
Wood	16.26	99.90	100
Animal meal	16.81	86.66	100
Sawdust	16.26	99.90	100
Agricultural waste / other biomass	12.72	110.00	100

The NCVs and CO_2 emission factors for waste oil, solvents, plastics, CSS, sewage sludge, animal meal and sawdust base on a study of Cemsuisse (Cemsuisse 2010a). The values for waste tyres are taken from Hackl, A., Mauschitz, G. (2003). The biogenic fraction of waste tyres is also based on an Austrian study and published by the German Ministry of Environment (UBA 2006). The origin of emission factors concerning the principle combustion fuels are explained in section 3.2.4.2.

Activity Data

Fossil fuels used in cement industry are coal (other bituminous coal and lignite), petroleum coke and, to a lesser extent residual fuel oil, natural gas and gas oil. In addition, also fossil and biogenic waste derived fuels are used. Fossil wastes comprise solvents and residues from distillation, waste tyres and rubbers, platics and waste oil whereas biogenic wastes contain mainly waste wood, animal residues and sewage sludge.

The amount of fossil and waste derived fuels consumed in cement industry is shown in Table Table 3-37. Data is provided by Cemsuisse and documented in EMIS2015/1A2f Zementwerke Feuerung.

Table 3-37 Activity data: Overview on fuel use in 1A2f cement industry. Fuels in italics: biogenic fuels.

Cement industry (part of 1A2f)	**Unit**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Cement industry											
Cement, total incl. waste	TJ	16'140	14'195	12'878	11'450	12'997	12'291	10'647	10'080	9'860	9'853
Cement fossil without waste	TJ	14'265	12'295	10'951	9'071	10'856	9'511	7'326	6'822	6'489	6'624
Gas oil	TJ	0	0	0	0	0	0	0	0	0	0
Residual fuel oil	TJ	1'907	2'957	4'377	3'263	4'589	2'825	3'507	3'206	3'168	3'260
Petroleum coke	TJ	900	670	50	500	980	830	550	240	410	466
Other bituminous coal	TJ	10'790	8'300	6'150	5'000	5'000	5'500	3'000	3'200	2'710	2'640
Lignite	TJ	306	353	306	259	259	188	236	165	139	136
Gas	TJ	362	14	67	48	27	168	34	10	62	121
Cement, waste derived fuel	TJ	1'874	1'901	1'927	2'379	2'142	2'780	3'321	3'258	3'371	3'229
Waste oil	TJ	1'169	1'137	1'104	1'527	1'208	1'485	1'514	1'257	1'509	1'403
Waste coke from coke filters	TJ	59	59	59	59	59	59	59	59	59	59
Mixed industrial waste	TJ	0	0	0	0	0	0	0	0	0	0
Other fossil waste fuels	TJ	0	0	0	0	0	0	0	0	0	0
Solvents and residues from distillation	TJ	284	378	473	284	127	181	274	410	375	272
Waste tyres and rubber	TJ	330	304	277	441	402	415	420	366	363	321
Plastics	TJ	0	0	0	0	27	55	177	274	508	553
Mix of special waste with saw dust (CSS)	TJ	23	14	5	51	147	136	111	100	118	132
Sewage sludge (dried)	TJ	9	9	9	19	65	128	175	240	216	279
Wood	TJ	0	0	0	0	106	321	395	319	0	0
Animal meal	TJ	0	0	0	0	0	0	197	233	223	211
Sawdust	TJ	0	0	0	0	0	0	0	0	0	0
Agricultural waste / other biomass	TJ	0	0	0	0	0	0	0	0	0	0

Cement industry (part of 1A2f)	**Unit**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Cement industry											
Cement, total incl. waste	TJ	10'582	11'054	10'756	10'490	11'281	11'623	11'719	12'022	11'954	11'816
Cement fossil without waste	TJ	6'897	6'553	5'754	5'231	5'514	6'208	6'401	6'914	6'389	6'127
Gas oil		0	0	0	0	55	72	57	0	0	0
Residual fuel oil	TJ	1'530	1'194	1'079	621	754	637	220	175	135	100
Petroleum coke	TJ	458	327	590	187	515	638	903	912	1'036	994
Other bituminous coal	TJ	4'750	4'950	3'980	4'330	4'080	4'120	3'383	4'033	3'618	3'650
Lignite	TJ	136	71	94	94	94	737	1'834	1'790	1'596	1'379
Gas	TJ	22	11	11	0	16	4	4	4	4	4
Cement, waste derived fuel	TJ	3'686	4'501	5'002	5'258	5'767	5'415	5'319	5'108	5'565	5'689
Waste oil	TJ	1'519	1'341	1'583	1'489	1'536	1'411	1'279	844	866	1'278
Waste coke from coke filters	TJ	59	59	59	59	46	58	60	0	0	0
Mixed industrial waste	TJ	0	0	0	0	0	0	0	2	1	1
Other fossil waste fuels	TJ	0	0	0	0	0	0	0	48	105	137
Solvents and residues from distillation	TJ	427	517	726	740	1'002	976	981	1'295	1'476	1'032
Waste tyres and rubber	TJ	421	476	460	568	519	645	568	525	794	828
Plastics	TJ	572	600	527	525	770	841	926	1'013	995	1'119
Mix of special waste with saw dust (CSS)	TJ	158	130	116	114	163	133	146	164	157	131
Sewage sludge (dried)	TJ	332	348	360	386	407	494	560	549	511	475
Wood	TJ	0	0	0	0	0	0	0	0	0	61
Animal meal	TJ	198	1'030	1'172	1'379	1'326	856	799	664	658	621
Sawdust	TJ	0	0	0	0	0	0	0	0	0	0
Agricultural waste / other biomass	TJ	0	0	0	0	0	0	0	5	2	7

Cement industry (part of 1A2f)	**Unit**	**2010**	**2011**	**2012**	**2013**
Cement industry					
Cement, total incl. waste	TJ	12'388	12'187	11'462	11'866
Cement fossil without waste	TJ	6'278	5'859	5'406	5'512
Gas oil		5	1	0	88
Residual fuel oil	TJ	112	101	297	86
Petroleum coke	TJ	1'130	1'081	920	815
Other bituminous coal	TJ	3'662	3'167	3'097	3'203
Lignite	TJ	1'348	1'493	1'081	1'283
Gas	TJ	21	16	11	38
Cement, waste derived fuel	TJ	6'109	6'329	6'056	6'354
Waste oil	TJ	1'253	1'170	839	876
Waste coke from coke filters	TJ	0	0	0	0
Mixed industrial waste	TJ	0	0	0	0
Other fossil waste fuels	TJ	45	55	36	25
Solvents and residues from distillation	TJ	1'189	1'264	1'294	1'414
Waste tyres and rubber	TJ	842	1'033	964	985
Plastics	TJ	1'252	1'163	1'092	1'299
Mix of special waste with saw dust (CSS)	TJ	123	96	100	96
Sewage sludge (dried)	TJ	477	483	527	418
Wood	TJ	292	409	586	732
Animal meal	TJ	624	614	572	479
Sawdust	TJ	6	24	17	32
Agricultural waste / other biomass	TJ	7	18	28	0

As shown in Table Table 3-37, in 2013 the Swiss cement industry used about 46% fossil fuels and 54% waste derived fuels. The most important fossil fuels in 2013 were other bituminous coal (58%), lignite (23%) and petroleum coke (15%).

Fuel consumption in cement plants has decreased by 26% between 1990 and 2013. This is partly due to a decrease in production since 1990 by about 15% and an increase in energy efficiency. In the same period the fuel mix has changed significantly from the use of mainly fossil fuels (88%) and some fossil waste derived fuels (11%) to the above mentioned mix of fuels (please note that waste derived fuels also contain biogenic fractions). The fossil fuels used in 1990 were bituminous coal, residual fuel oil and petroleum coke with shares of 75%, 13% and 6%, respectively, of the total fuel consumption.

Please note that all fossil waste derived fuels in the CRF-tables are reported under fuel type Other fossil fuels, whereas the biogenic waste derived fuels are reported in fuel type Biomass.

Brick and tile

In Switzerland there are about 20 plants producing bricks and tiles. Fossil fuels are used for drying and burning of the clay blanks.

Fuels used in the brick and tile production in 2013 are natural gas (72%), residual fuel oil (20%) as well as small amounts of gas oil (4%) and liquefied petroleum gas (4%). Apart from a production recovery in the years around 2004 the production has gradually decreased since 1990 by about 38% which is also represented in the overall fuel consumption decrease of about 38% as well. Regarding the fuels used, there has been a considerable shift from residual fuel oil to natural gas from 1990 onwards as well as a minor shift from gas oil and liquefied petroleum gas to natural gas from 2004 onwards. Small amounts of paper production residues, wood and animal grease are used since 2000.

The CO_2 emission factors for wood and the biogenic waste, i.e. paper production residues, and animal grease used in brick and tile production are 92 kg/GJ, 86 kg/GJ and 81 kg/GJ, respectively for animal grease. For geogenic CO_2 emissions an emission factor of 100 kg per ton of tile is applied (see documentation EMIS/1A2f Ziegeleien).

For CH_4 emission factors concerning principle fuel combustion including wood, default values according to IPCC 2006 are used (e.g. gas oil 06.g/GJ). For paper production residues, the same value as for wood is applied. For animal grease a value of 3g/GJ is used.

Also N_2O emission factors for principle fuel combustion are based on default values by IPCC 2006. For paper production residues the same value as for wood is applied. For animal grease a value of 6g/GJ is used.

Lime

In Switzerland there is only one plant producing lime. Fossil fuels are used for the burning process (calcination) of limestone. Between 1994 and 2012 fuel consumption in lime production is mainly based on residual fuel oil with a share of 99% in 2012. However in 2013 the main kiln has been switched to natural gas. Since 1995, no petroleum coke is used anymore as it was replaced by residual fuel oil. The fuel consumption of two sugar plants that autoproduce lime is reported in category 1A2e.

Fine ceramics

In Switzerland, the main production of fine ceramics is sanitary ware produced by one big and some small companies. In earlier years, also other ceramics were produced as for example glazed ceramics tiles, electrical porcelain and earthenware. Since 2001, only sanitary ware is produced.

Since 2010 fuel consumption within fine ceramics production is natural gas only. In 2001 the fuel-mix was natural gas (59%) and gas oil (37%). Since then, fuel mix has continuously shifted to natural gas. Compared to the production of other fine ceramics, the production of sanitary ware is more energy-intensive. Therefore, the specific energy use per tonne of produced fine ceramics has increased since 1990. This results in a lower reduction of fuel consumption (67%) compared to the reduction in production (79%) between 1990 and 2013.

Glass

In Switzerland glass production includes three types of glass: container glass, tableware glass and glass wool. Today there exist only one production plant for container glass and one for tableware glass. Glass wool is produced in two plants.

In 2013 fuel consumption for container glass production includes mainly residual fuel oil (58%) and natural gas (42%). Since 1990, fuel consumption for container glass has drastically decreased due to reduction in production. Until 2003 only residual fuel oil was used in container glass production. Since 2004 the share of natural gas has increased to reach a stable contribution of about 20% between 2006 and 2012. The large increase in natural gas share between 2012 and 2013 is due to the fact that the plant has switched its glass kiln completely to natural gas in autumn 2013.

Fuel consumption for tableware glass currently includes only liquefied petroleum gas. Since 1990 fuel consumption for tableware glass strongly decreased because of the closure of one production plant in 2002 and another one in 2006. In addition, the consumption of residual fuel oil is eliminated in 2000 (with shares of 17% and 21% in 1990 and 1995, respectively).

Fuel consumption for glass wool production includes currently only natural gas. Production of glass wool has increased since 1990 by approximately 61%, but the natural gas consumption decreased by approximately 12%. This can be explained by an increase in energy efficiency in the production process, i.e. a decrease of the specific energy consumption from 8.5 GJ/t to 4.8 GJ/t from 1990 to 2013.

Mixed goods

The production of mixed goods mainly includes the production of bitumen for road paving. A total of 110 production sites are producing mixed goods at stationary production sites.

The main fuel used in 2013 is gas oil (75%) and natural gas (25%). The specific fuel consumption per ton of mixed goods was assumed to be constant between 1990 and 2013 and production of mixed goods oscillates around five million tons per year. There has been a fuel switch from gas oil (reduction of 32%) to natural gas (increase of 28%) in this time.

Rock wool

In Switzerland there is one single producer of rock wool. Cupola furnaces are used for the melting of rocks at a temperature of 1500 °C.

Currently other bituminous coal (81%) and natural gas (19%) are used in the production process. Until 2004 also gas oil and liquefied petroleum gas were used which were substituted by natural gas in 2005. Rock wool production has increased by approximately 41% from 1990 to 2013 whereas the fuel consumption has increased by 33%.

Other (1A2g)

The source category 1A2g Other (stationary) is based on specific information from the industry as well as information from the Helbling statistics (SFOE 2014d).

Source category 1A2g includes fuel consumption of fibreboard production in1A2giv Wood and wood products, of non-road vehicles (1A2gvii) as well as of a variety of boilers and engines in the industry sector (1A2gviii). This source category accounts for approximately 43% of the overall fuel consumption in 1A2 Manufacturing Industries and Construction.

Fuel consumption of 1A2g Other in 2013 comprises mainly biomass (30%), gas oil (25%), natural gas (20%) and diesel oil (18%) (see Table 3-33). Overall in 1A2g there has been a switch in fuel consumption between 1990 and 2013 from liquid and solid fuels with shares of 47% and 12%, respectively, to liquid fuels, biomass and natural gas with shares of 31%, 30% and 20%, respectively (Table 3-33).

Since 1990 the consumption of residual fuel oil, liquefied petroleum gas and gas oil decreased by 100%, 46% and 53% respectively until 2013. Solid fossil fuel consumption also decreased by 97%. Biomass, gasoline and diesel oil consumption increased by 82%, 9% and 35% respectively.

1A2giv Fibreboard production: Fibreboards are produced in a two companies in Switzerland, where thermal energy is used for heating and drying processes. Current fuels used are waste wood (85%) and natural gas (12%). Since 1990 the production and thus the fuel consumption have increased significantly by a factor of 11. The fuel mix has strongly shifted between 1990 and 2013 from fossil fuels to biomass (waste wood), i.e. a reduction in fossil fuel share from 64% to 14% from 1990 to 2013. Since 2001 also small amounts of animal grease are.

Mobile (non-road) (1A2gvii): Source category 1A2gvii also accounts for diesel and gasoline for mobile construction and industrial machinery (non-road). The most relevant mobile construction machines in terms of fuel consumption are excavators, loaders, dump trucks and mobile compressors. In the industry sector, forklifts and snow groomers consume the most fuel, but the share of electrical forklifts has been gradually increasing. Almost all fuel consumed in 1A2gvii (98%) is diesel oil (98%), the rest is gasoline and natural gas. Activity data are taken from INFRAS (2008) and Keller/INFRAS (2013).

1A2gviii Other: In this source category all sorts of boilers, automated furnaces (pellet and woodchip), engines (biogas and sewage gas) and wood fired CHP installations in industry are subsumed. Methodologically appliances in this source category that use fossil fuels are the residual mass of the industry installations as modelled by Helbling (SFOE 2014d) that could not be allocated to one of source categories 1A2a-f. Furthermore activity data for wood combustion is based on wood statistics (SFOE 2014b). Further information about the pellet- and woodchip boilers is provided in 3.2.4.3. The dominant fuels used in this source category are gas oil (33%), natural gas (24%) and biomass (24%). A fuel shift occurred from liquefied petroleum gas (16%) in 1990 that now accounts for only 8% of total consumption. Overall fuel consumption however increased by 54% between 1990 and 2013.

3.2.6.3 Uncertainties and Time-Series Consistency

The uncertainty of CO_2 emissions from fuel combustions is described in the uncertainty analysis of the sector Energy (1A) in chapter 3.2.4.4. Uncertainty in emissions of other non-CO_2 gases is estimated to be medium, i.e. 30% for CH_4 and 80% for N_2O (see Table 1-11).

Consistency: Time series for 1A2 Manufacturing industries and construction are all considered consistent.

3.2.6.4 Source-specific QA/QC and Verification

The general QA/QC procedures are described in section 1.2.3. Furthermore QA/QC procedures conducted for all 1A source categories are listed in 3.2.4.5

3.2.6.5 Category-specific Recalculations

- 1A: The entire emission factor model for 1A1a, 1A2f, 1A2gviii, 1A4ai, 1A4bi and 1A4ci Wood combustion has been revised for 1990-2012 resulting in revised values for CH_4, CO and NMVOC.
- 1A: For wood combustion, the previously used country-specific value of the N_2O EF (1.6 g/GJ) has been replaced by the default value of the 2006 IPCC Guidlines (4.0 g/GJ) for the entire time series, based on a recommendation from the ERT (UNFCCC 2014c).
- 1A: In 1A1a, 1A2f, 1A2gviii, 1A4ai, 1A4bi and 1A4ci Wood combustion the AD (wood) of automatic boilers (> 50 kW) have been revised for 1990-2012 due to recalculations in the Swiss wood energy statistics.
- 1A: Revised activity data for 1A1-1A5 for all years from 1990-2013 and all fuels due to a large-scale revision of the Swiss overall energy statistics.
- 1A: The default CO_2 emission factor for natural gas was replaced by a country-specific emission factor for the entire time period from 1990-2013.
- 1A: In earlier submissions, petroleum coke was reported together with coal, therefore, the N_2O emission factor for petroleum coke used was equal to the default emission factor for coal (1.6 g/GJ). As petroleum coke is reported separately, default emission factor for petroleum coke from the IPCC Guidelines 2006 is used (0.6 g/GJ).
- 1A2c: In 1A2c Steam production cracker by-products the fuels liquefied petroleum gas and gas oil have been changed to so-called heating gas and gasolio, respectively, for the entire time series according to information from the plant. For the years 1990-2012 the CO_2 emission factors have been revised to plant-specific values whereas for CH_4

and N_2O emission factors default values according to 2006 IPCC Guidelines have been assumed.

- 1A2d: In source category 1A2d Cellulose production the CO_2 emissions from carbonate use for sulphur oxide removal are newly reported in the inventory of the years 1990-2008.
- 1A2f: AD and EF for Cement production (furnaces) are now related to tons of clinker, and not to tons of cement anymore. Therefore all data have been converted to this unit for the years 1990-2012.
- 1A2f: Cement industry; values for shares of fossil C in the alternative fuels solvents, plastics and special waste/sawdust mixes that have previously been rounded are now not being rounded anymore in the calculation for the EF CO_2. This leads to slightly different EF for these fuels.
- 1A2f: the activity data (tiles) of 1A2f Brick and tile production for 2012 have been corrected due to a data mistake in last year's submission.
- 1A2f: the AD of animal grease have been corrected in 1A2f Brick and tile production for 2000-2012 due to a mistake in last year's submission.
- 1A2f: the AD (gas oil, liquefied petroleum gas) of 1A2f Rockwool production have been revised for 1990-2000 based on a correction in the split between the two fuels in 1990. This results in revised interpolated values for 1991 to 2000 as well.
- 1A2f: the AD of animal grease have been corrected in 1A2f Brick and tile production for 2000-2012 due to a mistake in last year's submission.
- 1A2f: the AD of gas oil consumption have been revised in 1A2f Fine ceramics production for 2003-2012 based on new available data from industry.
- 1A2f: the EF of CO and NO_x from 1A2f Container glass production have been revised for 2006-2012 based on new data from air pollution control measurements.
- 1A2f: the SO_x EF from 1A2f Container glass production has been revised for 2011-2012 based on new data from air pollution control measurements.
- 1A2f: the EF of NO_x and NMVOC from 1A2f Lime production have been revised for 1990-2012 based on new data from air pollution control measurements.
- 1A2f: the EF of SO_x from 1A2f Lime production has been revised for 1994-2012 based on recent data from air pollution control measurements.
- 1A2f: the EF of NOx from 1A2f Mineral wool production has been revised for 2000-2012 based on air pollution control measurements

3.2.6.6 Source-Specific Planned Improvements

For submission 2016 the consideration of the revised non-road model is envisaged.

3.2.7 Source Category 1A3 - Transport

3.2.7.1 Source Category Description:

Key Categories in source category 1A3 Transport

Approach 1 Key Categories 1A3a

CO_2 from the combustion of fuel (kerosene) in Domestic aviation (trend)

Approach 2 Key Categories 1A3a

There are no Approach 2 Key categories in 1A3a

Approach 1 Key Categories 1A3b

CO_2 from the combustion of Gasoline in Road transportation (level and trend)
CO_2 from the combustion of Diesel in Road transportation (level and trend)
CH_4 from the combustion of Gasoline in Road transportation (trend)
N_2O from the combustion of Gasoline in Road transportation (trend)

Approach 2 Key Categories 1A3b

CH_4 from the combustion of Gasoline in Road transportation (trend)
N_2O from the combustion of Gasoline in Road transportation (trend)

The source category includes domestic aviation, road transportation, railways, domestic navigation and other transportation (only pipeline transportation). Note that non-road transportation is also relevant in category 1A2 Manufacturing Industries and Construction, in 1A4 Other Sectors and 1A5 Other (Military). For information on international bunker fuel emissions from international aviation and navigation, see Chapter 3.2.2.

Table 3-38 Specification of Swiss source category 1A3 Transport.

1A3	Source	Specification	Data Source
1A3a	Domestic aviation	Large (jet, turboprop) and small (piston) aircrafts, helicopters	AD: SFOE 2014, FOCA 2006, 2006a, FOCA 2007 - 2014,
1A3b	Road transportation	Light and heavy motor vehicles, coaches, two-wheelers	AD: SFOE 2014, SFCA 2014, SFSO 2014b, ARE 2012 Method, EF: INFRAS 2010, INFRAS 2011, FOEN 2010i, Hausberger et al. 2009
1A3c	Railways	Diesel locomotives	Method, AD, EF: INFRAS 2008 AD: Prognos 2012, Keller/INFRAS 2013
1A3d	Domestic navigation	Passenger ships, motor and sailing boats an the Swiss lakes and the river Rhine	Method, AD, EF: INFRAS 2008 AD: Keller/INFRAS 2013, Prognos 2012
1A3e	Other transportation - Pipeline compressors	Compressor station in Ruswil, Lucerne	AD: SFOE 2014 EF: Battelle 1994, SAEFL 2000, Quantis 2014, Xinmin 2004

3.2.7.2 Methodological Issues

a) Domestic Aviation (1A3a)

Methodology

The emissions of domestic aviation are modelled by a Tier 3a method developed by FOCA (2006) together with the international aviation reported in 1D1 (aviation bunker, see chapter 3.2.2). FOCA is represented in the emissions technical working group (CAEP WG3) and in the modelling and database group (CAEP MDG) of the International Civil Aviation Organisation (ICAO). FOCA is directly involved in the development of ICAO guidance material for the calculation of aircraft emissions and in the update of the IPCC guidelines (via the secretariat of ICAO CAEP (Committee on Aviation Environmental Protection). The Tier 3a method applied for the emission modelling is in line with the methods developed in the working groups mentioned. Note that the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006) have been prepared by the IPCC Task Force on National Greenhouse Gas Inventories and have been adopted in April 2006 by the IPCC. The modelling scheme for domestic aviation refers to aircraft basic data, activity data and emission factors that result in calculated emissions. Respective values are ultimately imported into the EMIS database as shown in Figure 3-16.

The Tier 3a method follows standard modelling procedures on the level of single movements based on detailed movement statistics. The primary key for all calculations is the aircraft tail number, which allows to calculate on the most precise level, namely on the level of the individual aircraft and engine type. Every aircraft is linked to the FOCA engine data base containing emission factors for more than 600 individual engine types with different power settings. Emissions in the landing and take-off cycle (LTO) are calculated with aircraft category dependent flight times and corresponding power settings. Cruise emissions are calculated based on the individual aircraft type and the trip distance for every flight. For piston-engine powered aircraft and helicopters, to the knowledge of FOCA, it has been the only provider of publicly available engine data and a full methodology. All piston engine data and study results have been published in 2007 (FOCA 2007a). The guidance on the determination of helicopter emissions has been published in 2009 (FOCA 2009a).

The movement database from Swiss airports registers the departure and destination airports of each flight. With this information, all flights from and to Swiss airports are differentiated into domestic and international flights prior to the emission calculation. The emissions of domestic flights are reported under 1A3a Domestic Aviation, the emissions of international flights are reported under 1D1 international aviation (international bunkers).

The emission factors used are either country-specific or taken from the ICAO engine emissions databank, from EMEP/CORINAIR databases (EMEP/EEA 2002), Swedish Defence Research Agency (FOI) and Swiss FOCA measurements (precursors). Cruise emission factors are generally calculated from the values of the ICAO engine emissions databank, adjusted to cruise conditions by using the Boeing Fuel Flow Method 2. For N_2O, the IPCC default emission factor is used. Activity data are derived from a detailed movement statistics.

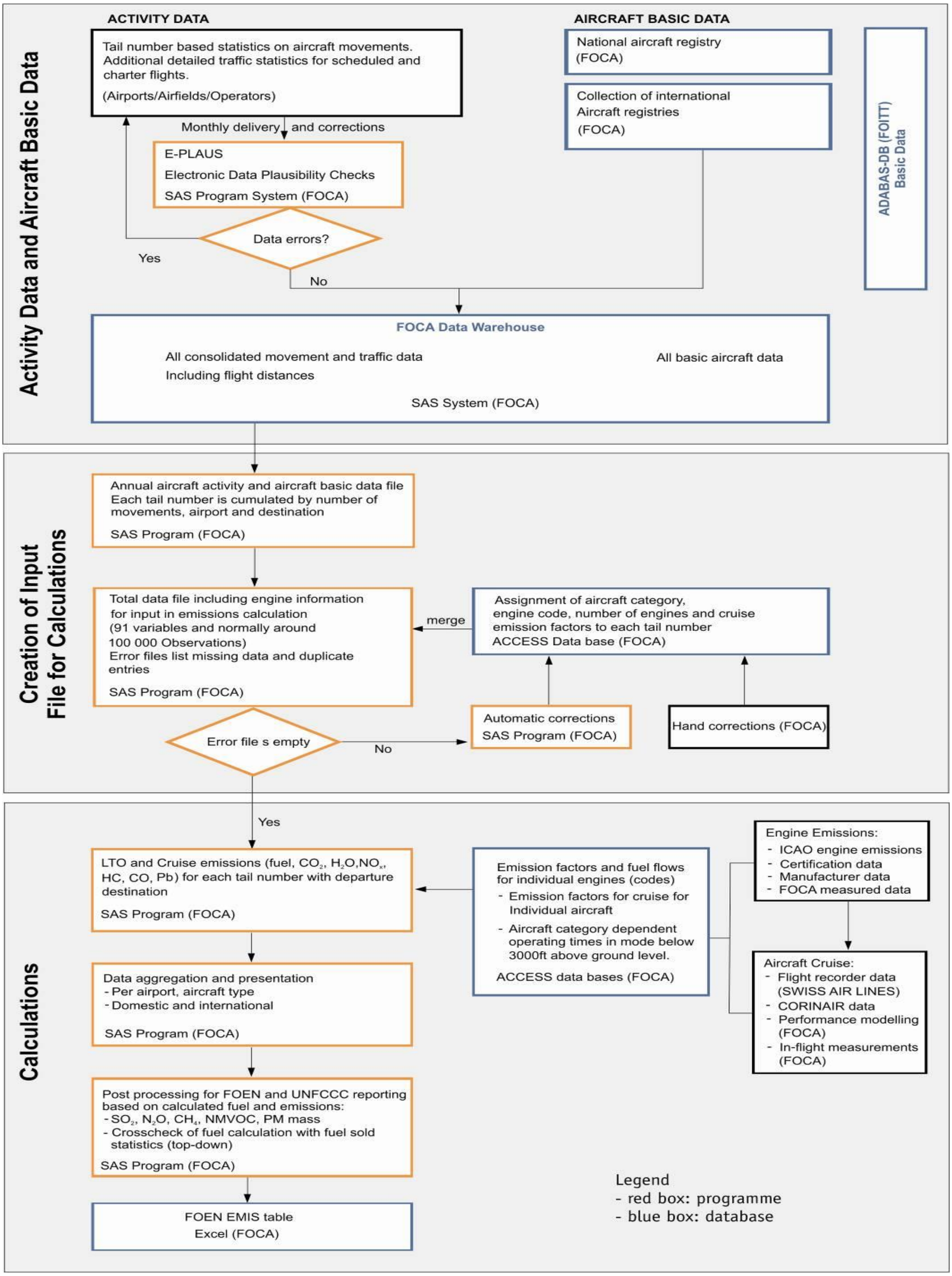


Figure 3-16 Modelling scheme (activity data, emission factors, emissions) for domestic aviation.

A complete emission modelling (LTO and cruise emissions for domestic and international flights) has been carried out by FOCA for 1990, 1995, 2000, 2002, 2004–2013. The results of the emission modelling have been transmitted from FOCA to FOEN in an aggregated form.

FOEN calculated the implied emission factors 1990, 1995, 2000, 2002, 2004 and carried out a linear interpolation for the years in-between. The interpolated implied emission factors were multiplied with the annual fuel sold from Swiss overall energy statistics (SFOE in respective years), providing the missing emissions of domestic aviation for the years 1991-1994, 1996-1999, 2001 and 2003.

Details of emission factors and activity data follow below. Further tables containing more information are also given in Annex A3.1.2, more detailed descriptions of the emission modelling may be found in FOCA (2006).

Emission Factors

Kyoto gases:

- CO_2: the emission factor of 72.8 t/TJ in 2013 is country-specific and is based on measurements and analyses of fuel samples (see Table 3-11).
- CH_4, NMVOC (country-specific; CORINAIR): VOC emissions (see Precursors below) are split into CH_4 and NMVOC by a constant share of 0.1 (CH_4) and 0.9 (NMVOC)[7]. For CH_4, the average emission factor for domestic flights is 1.9 kg/TJ in 2013, average LTO is 3.4 kg/TJ (international airports only), cruise 0.72 kg/TJ (international airports only) (FOCA 2014).
- N_2O: A country-specific value of 2.3 kg/TJ is used for the whole period 1990-2013.

Precursors (country-specific; CORINAIR):

- SO_2: The emission factors is country-specific determined to be 23 kg/TJ and remains constant for the entire time series from 1990-2013.
- Assignment of emission factors for 1990 and 1995: The fleet that operated in and from Switzerland during those years has been analysed. The corresponding most frequent engines within an aircraft category (ICAO Code) have been assigned to every aircraft type.
- Assignment of emission factors for the year 2000, 2002, 2004 to 2013: the actual engine of every single aircraft operating in and from Switzerland has been assigned. FOCA uses the aircraft tail number as the key variable which links activity data and individual aircraft engine information (see Annex A 3.1.2 Table A – 13 Aircraft Engine Combinations).

FOCA determines the emission factors of different precursors such as NO_x, VOC, CO and other pollutants as follows:

[7] The share of 0.1 for methane is maintained until general acceptance of necessary corrections is reached. Studies indicate that during cruise, Methane exhaust concentrations are lower than Methane ambient concentrations, see Wiesen et al. (1994), Spicer et al. (1994) and Knighton et al. (2009).

LTO:

The FOCA engine emissions database consists of more than 600 individual engine data sets. Jet engine factors for engines above 26.7 kN thrust (emission certificated) are identical to the ICAO engine emissions databank. Emission factors for lower thrust engines, piston engines and helicopters were taken from manufacturers or from own measurements. Emission factors for turboprops could be obtained in collaboration with the Swedish Defence Research Agency (FOI).

Cruise:

The fuel flows of the whole Airbus fleet (which produces a great portion of the Swiss inventory) have been modelled on the basis of real operational aircraft data from flight data recorders (FDR) of Swiss International Airlines. Pollutant emission factors have been modelled on the basis of the ICAO engine databank and corrected to cruise conditions using FDR engine parameters and the Boeing Fuel Flow Method 2. Part of the cruise emission factors are taken from EMEP/CORINAIR (EMEP/EEA 2002) and from former CROSSAIR (FOCA 1991). Other missing aircraft types have been modelled on the basis of FOCA aircraft performance modelling and the ICAO engine emissions databank, using the Boeing Fuel Flow Method 2, as well. For piston engine aircraft and helicopters, Swiss FOCA has produced its own data, which were taken under real flight conditions (2005 data, FOCA 2009a).

Activity Data

Scheduled and charter aviation

The statistical basis has been extended after 1996. Therefore, the modelling details are not exactly the same for the years 1990-1995 as for the subsequent years. The source for the 1990 and 1995 modelling is the movement statistics, which records information for every movement on airline, number of seats, Swiss airport, arrival/departure, origin/destination, number of passengers, distance. From 1996 onwards, every movement in the FOCA statistics also contains the individual aircraft tail number (aircraft registration). This is the key variable to connect airport data and aircraft data. The statistics may contain more than one million records with individual tail numbers. All annual aircraft movements recorded are split into domestic and international flights (there are 447’737 aircraft movements in the total of scheduled and charter traffic in 2013 as provided by FOCA 2014).

Non-scheduled, non-charter and general aviation (including Helicopters)

- Airports and most of the airfields report individual aircraft data (aircraft registration). FOCA may therefore compute the inventory for small aircraft with Tier 3a method, too. However, for 1990 and 1995, the emissions data for non-scheduled, non-charter and General Aviation (helicopters etc.) could not be calculated with a Tier 3a method. Its fuel consumption is estimated to be 10% of the domestic fuel consumption. Data were taken from two FOCA studies (FOCA 1991, FOCA 1991a). For 2000-2007, all movements from airfields are known, which allows a more detailed modelling of the emissions (FOCA 2007a).

- Helicopter flights which do not take off from an official airport or airfield such as transport flights, flights for lumbering, animal transports, supply of alpine huts, heli-skiing and flight trainings in alpine regions cannot be recorded with the movement data base from airports and airfields. Although these helicopter movements only account for 0.1% of the total domestic aviation emissions, these emissions are taken into account using the Unternehmensstatistik der Schweizer Helikopterunternehmen. This statistics is officially collected by FOCA and updated annually (see FOCA 2004 as illustrative example for all subsequent years).
  Since 2007, the data of the Unternehmensstatistik der Schweizer Helikopterunternehmen (statistics about Swiss helicopter companies) is included electronically in the data warehouse of the model and undergoes first some plausibility checks (E-plaus software). In order to distinguish between single engine helicopters and twin engine helicopter a fix split of 87 % for single engine helicopters and 13 % for twin engine helicopters is applied for the entire commitment period based on investigations in 2004 (FOCA 2004). Note that all emissions from helicopter flights without using an official airport or an official airfield are considered as domestic emissions.

Fuel consumption: Table 3-39 summarises the activity data for domestic aviation (1A3a). It also includes international aviation, which belongs to the memo items, international bunkers/aviation (see also Chapter 3.2.2). In order to determine the fuel consumption from International bunkers the following procedure is applied: from the total kerosene consumption the consumption from domestic aviation, military aviation and helicopter flights in Liechtenstein is deducted. The emission model run by FOCA overestimates fuel consumption by ca. 1.1%. However, the domestic fuel consumption is reported according to the modelled value (conservative estimation), whereas the international fuel consumption (bunker) is scaled downwards so that the sum of domestic and international fuel consumption becomes identical with the fuel sold, as reported in the Swiss overall energy statistics.

Table 3-39 Fuel consumption of domestic aviation in TJ. The "domestic" consumption and the corresponding emissions are reported under 1A3a, the "international" consumption is reported under Memo items, international bunkers (FOCA 2007, 2007a, 2008-2014).

1A3a/1D1 Aviation	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
	Fuel consumption in TJ									
Total domestic (1A3a)	3'450	3'194	3'217	3'165	3'077	3'075	2'972	2'850	2'742	2'684
Total international (1D1)	41'884	40'872	43'499	45'342	46'840	49'918	51'975	53'983	56'599	60'805
Sum	45'334	44'067	46'717	48'508	49'917	52'993	54'946	56'833	59'341	63'489
1990 = 100%	100%	97%	103%	107%	110%	117%	121%	125%	131%	140%

1A3a/1D1 Aviation	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
	Fuel consumption in TJ									
Total domestic (1A3a)	2'539	2'296	2'028	1'951	1'963	1'699	1'658	1'891	1'618	1'704
Total international (1D1)	63'687	60'097	55'468	49'763	46'896	47'671	50'109	53'543	57'844	55'238
Sum	66'225	62'393	57'495	51'714	48'859	49'370	51'766	55'434	59'462	56'942
1990 = 100%	146%	138%	127%	114%	108%	109%	114%	122%	131%	126%

1A3a/1D1 Aviation	**2010**	**2011**	**2012**	**2013**
	Fuel consumption in TJ			
Total domestic (1A3a)	1'688	1'808	1'867	1'817
Total international (1D1)	58'118	62'211	63'627	64'709
Sum	59'805	64'019	65'494	66'526
1990 = 100%	132%	141%	144%	147%

b) Road Transportation (1A3b)

Methodology

CO_2:

The CO_2 emissions are calculated with a Tier 2 method (top-down) as suggested by 2006 IPCC Guidelines (IPCC 2006) using country-specific emission factors. The emission factors are derived from the carbon content of fuels (see Table 3-11). The activity data corresponds to the amounts of gasoline and diesel fuel sold in Switzerland (sales principle). The numbers are taken from the national fuel statistics which is part of the Swiss overall energy statistics (SFOE 2014).

The consumption of biofuels is reported for Road Transportation as well. Fuels involved, emission factors and activity data are summarised in a comment to the EMIS database (EMIS 2015/1A3bi-viii Strassenverkehr). Most important data sources stem from the Swiss overall energy statistics (SFOE 2014) the Swiss renewable energy statistics (SFOE 2014a) and the Swiss Federal Customs Administrations (SFCA 2014).

The use of urea in urea-based catalysts is reported under 2D3 in section 4.5.2 as recommended in the CRF table's footnotes.

Other gases:

The other gases are modelled by means of a Tier 3 method with a well-documented country-specific method (SAEFL 1995, 2004a, FOEN 2010i, INFRAS 2010, INFRAS 2011, Hausberger et al. 2009).

The emission computation is based on two sets of data:

- Traffic activity data: transport performance in vehicle kilometres (hot emissions), number of starts/stops and vehicle stock (cold start, evaporation emissions and running losses) or fuel consumption per vehicle category.
- Emission factors: specific emissions in grams per unit (vehicle kilometres, start/stop or vehicle or fuel consumption).

For the calculation of emissions these two data sets are multiplied for all other gases as follows (further details of emission modelling are given in Annex A3.1.3):

Emission (*gram*) = activity data (*veh-km/a, starts/stops/a, number of vehicles, fuel consumption (GJ)*) * emission factor (*gram/veh-km, gram/start/stop, gram/vehicle, gram/GJ*),

Emission Factors

The emission factors for fossil CO_2 are country-specific and based on measurements and analyses of fuel samples (Table 3-11). Emission factors for other gases are country-specific derived from “emission functions” which are determined from a compilation of measurements from various European countries with programs using similar driving cycles (legislative as well as standardized real-world cycles, like “Common Artemis Driving Cycle” (CADC). The method has been developed in 1990-1995 and has been extended and updated in 2000, 2004 and 2010. These emission factors are compiled in a “Handbook of Emission Factors for Road Transport” (SAEFL 1995, 2004a, FOEN 2010i, INFRAS 2004, 2010, 2011). Version 3.1 is presented and documented on the website http://www.hbefa.net/. Several reports may be downloaded from there:

- Documentation of the general emission factor methodology (INFRAS 2011; forthcoming in German),
- Emission Factors for Passenger Cars and Light Duty Vehicles Switzerland, Germany, Austria, Norway and Sweden (INFRAS 2010; in English),

The resulting emission factors are published on CD ROM (“Handbook of emission factors for Road Transport”, INFRAS 2010). The underlying database contains a dynamic fleet compositions model simulating the release of new exhaust technologies and the fading out of old technologies. Corrective factors are provided to account for future technologies. Further details are shown in Annex A3.1.3.

The following tables Table 3-40 and Table 3-41 present a selection of mean emission factors. The CO_2 factors of gasoline, diesel and CNG are linearly interpolated over the whole period 1998–2013 between the years where measurements are available (Table 3-11,

Table 3-12) and kept constant for the years before. For the other gases, more or less pronounced decreases of the emission factors occur due to new emission regulations and subsequent new exhaust technologies (mandatory use of catalytic converters for gasoline cars and lower limits for sulphur content in diesel fuels). Early models of catalytic converters have been substantial sources of N_2O, leading to an emission increase until 1998. Recent converter technologies have overcome this problem resulting in a decrease of the (mean) emission factor.

As of submission 2013 of the National Inventory Report, N_2O emission factors in g/km differentiated by vehicle category and technology from the Handbook of Emission Factors (INFRAS 2010) have been applied, in contrast to previous submissions that applied a constant value in g/TJ fuel consumption. This results in a more realistic change pattern over time of N_2O emissions from road transportation than in earlier submissions.

In contrast to the N_2O emission factors, the measurement sample for CH_4 emission factors remained the same. However, due to updates in the vehicles fleet composition, the implied emission factors changed eventually. Further detailed description of how the emission factors for CH_4 are estimated is provided in the Annex A3.1.3.

Also as of submission 2013, N_2O emission factors for gaseous fuels have been applied. No country-specific EFs for N_2O are available. Therefore, emissions have been estimated using the EFs for alternative fuel vehicles provided in table 3.2.4 on page 3.23 of Volume 2 of the 2006 IPCC Guidelines (IPCC 2006). The value of 101 mg/km from the 2006 IPCC Guidelines was used for urban buses running on CNG only. For the bi-fuel passenger cars, it is assumed that they use gasoline mainly during the start but otherwise run on CNG; therefore the respective CNG emission factor for light duty vehicles of 27 mg/km from the same source was applied. As for all other fuel categories, the emission factor used for fuel tourism and statistical differences corresponds to the weighted average of the national transport mix.

Emission factors from the combustion of biofuels

In lieu of reviewed emission factors for biofuels, the following assumptions were made (here as example for passenger cars, see also Table 3-40 and Table 3-41 below):

- Biodiesel: the implied emission factors 1A3b for fossil diesel are used. Values for 2013:
  CO_2 73.3 t/TJ; CH_4 0.3 kg/TJ; N_2O 2.2 kg/TJ
- Bioethanol: the implied emission factors 1A3b for gasoline are used. Values for 2013:
  CO_2 73.8 t/TJ; CH_4 5.5 kg/TJ; N_2O 0.6 kg/TJ
- Biogas: the implied emission factors 1A3b for CNG are used. Values for 2013:
  CO_2 56.4 t/TJ; CH_4 5.3 kg/TJ; N_2O 8.4 kg/TJ

Overview on mean emission factors:

Table 3-40 Mean emission factors for road transport for passenger cars. For more details see Annex A3.1.3.

Gas	Fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Passenger Cars		t/TJ									
CO_2	Gasoline	73.9	73.9	73.9	73.9	73.9	73.9	73.9	73.9	73.9	73.9
	Diesel	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6
	CNG										
CH_4	Gasoline	0.0266	0.0237	0.0213	0.0196	0.0178	0.0166	0.0155	0.0143	0.0132	0.0123
	Diesel	0.0015	0.0015	0.0013	0.0012	0.0013	0.0012	0.0011	0.0010	0.0009	0.0009
	CNG										
N_2O	Gasoline	0.0031	0.0033	0.0035	0.0037	0.0039	0.0041	0.0042	0.0042	0.0041	0.0039
	Diesel	0.0002	0.0003	0.0004	0.0005	0.0007	0.0008	0.0009	0.0010	0.0012	0.0014
NO_x	Gasoline	0.3449	0.3139	0.2832	0.2657	0.2568	0.2512	0.2469	0.2377	0.2274	0.2163
	Diesel	0.2527	0.2558	0.2463	0.2395	0.2457	0.2412	0.2404	0.2402	0.2422	0.2464
	CNG										
CO	Gasoline	3.1952	2.7878	2.4249	2.1754	1.9608	1.7979	1.6596	1.5308	1.4167	1.3193
	Diesel	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	CNG										
NMVOC	Gasoline	0.5008	0.4402	0.3865	0.3485	0.3131	0.2861	0.2623	0.2396	0.2192	0.2013
	Diesel	0.0608	0.0617	0.0547	0.0504	0.0515	0.0471	0.0445	0.0410	0.0380	0.0352
	CNG										
SO_2	Gasoline	0.0094	0.0094	0.0094	0.0094	0.0094	0.0094	0.0094	0.0094	0.0094	0.0094
	Diesel	0.3678	0.3651	0.3348	0.3076	0.2860	0.2656	0.2555	0.2365	0.2222	0.2079
	CNG										

Gas	Fuel	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Passenger Cars		t/TJ									
CO_2	Gasoline	73.9	73.9	73.9	73.9	73.9	73.9	73.8	73.8	73.8	73.8
	Diesel	73.6	73.5	73.5	73.5	73.5	73.5	73.4	73.4	73.4	73.4
	CNG								56.5	56.5	56.4
CH_4	Gasoline	0.0114	0.0106	0.0098	0.0092	0.0086	0.0082	0.0076	0.0073	0.0069	0.0064
	Diesel	0.0008	0.0007	0.0006	0.0006	0.0006	0.0005	0.0004	0.0004	0.0004	0.0003
	CNG								0.0045	0.0043	0.0042
N_2O	Gasoline	0.0037	0.0034	0.0032	0.0029	0.0017	0.0016	0.0013	0.0013	0.0011	0.0010
	Diesel	0.0015	0.0017	0.0018	0.0019	0.0019	0.0020	0.0020	0.0020	0.0021	0.0021
NO_x	Gasoline	0.2050	0.1925	0.1772	0.1646	0.1528	0.1433	0.1263	0.1192	0.1075	0.0964
	Diesel	0.2543	0.2653	0.2765	0.2873	0.2922	0.2905	0.2774	0.2677	0.2594	0.2544
	CNG								0.0236	0.0232	0.0232
CO	Gasoline	1.2355	1.1774	1.1157	1.0698	1.0252	0.9934	0.9310	0.9065	0.8612	0.8144
	Diesel	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	CNG								0.0842	0.0837	0.0841
NMVOC	Gasoline	0.1846	0.1722	0.1590	0.1486	0.1396	0.1334	0.1233	0.1200	0.1131	0.1063
	Diesel	0.0324	0.0293	0.0261	0.0243	0.0224	0.0205	0.0177	0.0164	0.0151	0.0140
	CNG								0.0004	0.0004	0.0004
SO_2	Gasoline	0.0067	0.0057	0.0048	0.0038	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
	Diesel	0.1832	0.1642	0.1448	0.1322	0.1131	0.1032	0.0903	0.0844	0.0785	0.0731
	CNG								0.0000	0.0000	0.0000

Gas	Fuel	2010	2011	2012	2013
Passenger Cars		t/TJ			
CO_2	Gasoline	73.8	73.8	73.8	73.8
	Diesel	73.4	73.3	73.3	73.3
	CNG	56.4	56.6	56.5	56.4
CH_4	Gasoline	0.0060	0.0059	0.0057	0.0055
	Diesel	0.0003	0.0003	0.0003	0.0003
	CNG	0.0041	0.0054	0.0054	0.0053
N_2O	Gasoline	0.0009	0.0008	0.0007	0.0006
	Diesel	0.0021	0.0021	0.0022	0.0022
NO_x	Gasoline	0.0861	0.0791	0.0726	0.0667
	Diesel	0.2509	0.2487	0.2475	0.2457
	CNG	0.0231	0.0221	0.0221	0.0222
CO	Gasoline	0.7755	0.7530	0.7299	0.7100
	Diesel	0.0000	0.0000	0.0000	0.0000
	CNG	0.0839	0.1578	0.1570	0.1567
NMVOC	Gasoline	0.1013	0.0991	0.0965	0.0944
	Diesel	0.0133	0.0130	0.0127	0.0126
	CNG	0.0004	0.0005	0.0005	0.0005
SO_2	Gasoline	0.0004	0.0004	0.0004	0.0004
	Diesel	0.0693	0.0673	0.0652	0.0638
	CNG	0.0000	0.0000	0.0000	0.0000

Table 3-41 Mean emission factors for road transport for heavy duty vehicles. For more details see Annex A3.1.3.

Gas	Fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Heavy duty vehicles		t/TJ									
CO_2	Diesel	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6
CH_4	Diesel	0.0019	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014
N_2O	Diesel	0.0007	0.0007	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0009	0.0009
NO_x	Diesel	1.029	1.028	1.025	1.016	0.986	0.956	0.935	0.920	0.911	0.902
CO	Diesel	0.219	0.218	0.218	0.214	0.206	0.201	0.196	0.191	0.184	0.178
NMVOC	Diesel	0.076	0.075	0.075	0.073	0.068	0.066	0.065	0.062	0.059	0.056
SO_2	Diesel	0.065	0.061	0.056	0.047	0.020	0.016	0.017	0.016	0.019	0.021

Gas	Fuel	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Heavy duty vehicles		t/TJ									
CO_2	Diesel	73.6	73.5	73.5	73.5	73.5	73.5	73.4	73.4	73.4	73.4
CH_4	Diesel	0.0013	0.0011	0.0010	0.0010	0.0009	0.0009	0.0008	0.0007	0.0005	0.0004
N_2O	Diesel	0.0009	0.0008	0.0008	0.0008	0.0007	0.0007	0.0009	0.0012	0.0017	0.0024
NO_x	Diesel	0.879	0.833	0.795	0.757	0.716	0.699	0.667	0.626	0.552	0.490
CO	Diesel	0.171	0.162	0.158	0.157	0.151	0.150	0.147	0.144	0.140	0.138
NMVOC	Diesel	0.053	0.046	0.043	0.040	0.036	0.035	0.031	0.028	0.022	0.017
SO_2	Diesel	0.0127	0.0117	0.0110	0.0093	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005

Gas	Fuel	2010	2011	2012	2013
Heavy duty vehicles		t/TJ			
CO_2	Diesel	73.4	73.3	73.3	73.3
CH_4	Diesel	0.0004	0.0003	0.0002	0.0002
N_2O	Diesel	0.0028	0.0032	0.0034	0.0037
NO_x	Diesel	0.451	0.416	0.390	0.367
CO	Diesel	0.136	0.135	0.134	0.132
NMVOC	Diesel	0.015	0.012	0.010	0.009
SO_2	Diesel	0.0005	0.0005	0.0005	0.0005

Activity Data

i) Fuel-related activity (basis for modelling the CO_2 emissions)

The amount of gasoline and diesel fuel sold in Switzerland serves as the activity data for the calculation of the CO_2 emissions: The Swiss overall energy statistics gives the amount of gasoline and diesel oil sold for Switzerland and the Principality of Liechtenstein (SFOE 2014). From these numbers, Liechtenstein's sales, the non-road consumption and the fugitive emissions from transmission, storage and fuelling of gasoline (reported under 1B2av Distribution of oil products) are subtracted. The result gives the inventory-relevant consumption for estimating the CO_2 emissions. It contains the fuel consumption due to the traffic model plus the amount of fuel tourism and statistical differences. Table 3-42 below shows the details.

The emissions from natural gas combustion for road transportation originate from activity data of two vehicle categories: biofuel CNG/petrol passenger cars and urban buses running purely on CNG. Data source is SFCA (2014). Numbers are also shown in Table 3-42.

As mentioned above that the figures for fuel sold in Table 3-42 also contain non-road consumption. These contributions do, of course, not account for road transportation and are therefore subtracted. The relevant numbers for road transportation are given as two different contributions in the rows "on road fuel consumption (model)" and "fuel tourism and statistical differences". This distinction is required for the modelling of the non-CO_2 gases as will be explained below.

Consumption of biofuels for road transportation starts in Switzerland in 1997. Time series of biodiesel, bioethanol and biogas sold are given in Table 3-43.

Table 3-42 Split of fuel sales into territorial on-road (model), non-road (models) and fuel tourism and statistical differences (residual value to sales amounts) for gasoline, diesel oil and natural gas in PJ. (Numbers may not add to totals due to rounding.)

Activity data	**Source**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
on-road and non-road categories	**category**					PJ					
Gasoline											
on-road consumption (model)	1A3b	135.6	139.0	137.6	134.5	137.6	140.8	142.3	142.9	143.9	145.3
fuel tourism and statistical differences	1A3b	17.8	20.8	28.1	19.0	16.1	8.1	10.5	16.0	16.3	20.4
non-road consumption (models)	1A2gvii; 1A3dii; 1A4aii,bii,cii; 1A5b	2.4	2.4	2.4	2.4	2.4	2.4	2.3	2.3	2.3	2.3
Gasoline sold in Switzerland		155.8	162.2	168.1	155.9	156.1	151.3	155.2	161.2	162.5	168.0
Diesel oil											
on-road consumption (model)	1A3b	36.5	37.4	38.3	38.1	39.0	39.8	39.7	40.0	41.1	42.7
fuel tourism and statistical differences	1A3b	-1.3	-1.8	-4.5	-6.2	-4.6	-4.8	-7.7	-6.5	-5.8	-4.7
non-road consumption (models)	1A2gvii; 1A3c,dii; 1A4cii; 1A5b	11.6	11.8	12.1	12.3	12.6	12.8	13.0	13.2	13.4	13.6
Diesel oil sold in Switzerland		46.7	47.4	45.9	44.2	46.9	47.8	44.9	46.7	48.7	51.6
Total gasoline and diesel oil											
on-road consumption (model)	1A3b	172.0	176.4	175.9	172.6	176.6	180.6	182.0	182.9	185.0	188.0
fuel tourism and statistical differences	1A3b	16.5	19.0	23.7	12.9	11.5	3.3	2.8	9.5	10.5	15.8
non-road consumption (models)	1A2gvii; 1A3c,dii; 1A4aii,bii,cii; 1A5b	14.0	14.2	14.5	14.7	14.9	15.2	15.3	15.5	15.7	15.9
Gasoline and diesel oil sold in Switzerland		202.5	209.6	214.0	200.1	203.0	199.1	200.1	207.9	211.1	219.6
Natural gas											
on-road consumption (model)	1A3b	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
fuel tourism and statistical differences	1A3b	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
non-road consumption (models)	1A2gvii	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural gas sold in on- and non-road categories		0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Activity data	**Source category**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
on-road and non-road categories						PJ					
Gasoline											
on-road consumption (model)	1A3b	146.9	145.5	144.5	141.9	139.1	136.1	132.1	129.1	126.4	122.8
fuel tourism and statistical differences	1A3b	18.9	15.7	13.5	15.5	15.5	13.8	13.1	14.7	14.3	14.0
non-road consumption (models)	1A2gvii; 1A3dii; 1A4aii,bii,cii; 1A5b	2.3	2.3	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Gasoline sold in Switzerland		168.1	163.5	160.3	159.6	156.8	152.0	147.4	146.0	142.8	139.0
Diesel oil											
on-road consumption (model)	1A3b	44.9	45.8	47.4	50.5	54.1	57.4	61.1	65.3	68.2	70.8
fuel tourism and statistical differences	1A3b	-3.5	-3.3	-2.9	-2.6	-1.6	1.1	3.3	4.7	10.1	8.9
non-road consumption (models)	1A2gvii; 1A3c,dii; 1A4cii; 1A5b	13.7	13.8	13.9	13.9	14.0	14.1	14.2	14.4	14.6	14.7
Diesel oil sold in Switzerland		55.2	56.3	58.4	61.8	66.5	72.6	78.6	84.4	92.9	94.5
Total gasoline and diesel oil											
on-road consumption (model)	1A3b	191.7	191.3	191.9	192.4	193.1	193.5	193.2	194.4	194.6	193.6
fuel tourism and statistical differences	1A3b	15.5	12.4	10.6	12.8	13.9	14.8	16.4	19.5	24.4	22.9
non-road consumption (models)	1A2gvii; 1A3c,dii; 1A4aii,bii,cii; 1A5b	16.0	16.1	16.1	16.1	16.2	16.2	16.4	16.6	16.7	16.9
Gasoline and diesel oil sold in Switzerland		223.3	219.8	218.7	221.4	223.2	224.6	226.0	230.4	235.7	233.5
Natural gas											
on-road consumption (model)	1A3b	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1
fuel tourism and statistical differences	1A3b	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.5
non-road consumption (models)	1A2gvii	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural gas sold in on- and non-road categories		0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.5	0.6

Activity data	**Source category**	**2010**	**2011**	**2012**	**2013**
on-road and non-road categories			PJ		
Gasoline					
on-road consumption (model)	1A3b	119.3	116.0	112.7	109.4
fuel tourism and statistical differences	1A3b	12.7	10.8	9.6	7.3
non-road consumption (models)	1A2gvii; 1A3dii; 1A4aii,bii,cii; 1A5b	2.2	2.1	2.1	2.1
Gasoline sold in Switzerland		134.1	128.9	124.4	118.7
Diesel oil					
on-road consumption (model)	1A3b	73.9	75.1	76.3	77.5
fuel tourism and statistical differences	1A3b	9.4	11.0	16.1	19.8
non-road consumption (models)	1A2gvii; 1A3c,dii; 1A4cii; 1A5b	14.9	14.8	14.7	14.5
Diesel oil sold in Switzerland		98.2	100.9	107.1	111.9
Total gasoline and diesel oil					
on-road consumption (model)	1A3b	193.2	191.1	189.0	186.9
fuel tourism and statistical differences	1A3b	22.1	21.8	25.7	27.1
non-road consumption (models)	1A2gvii; 1A3c,dii; 1A4aii,bii,cii; 1A5b	17.1	16.9	16.8	16.6
Gasoline and diesel oil sold in Switzerland		232.3	229.8	231.5	230.6
Natural gas					
on-road consumption (model)	1A3b	0.2	0.2	0.3	0.3
fuel tourism and statistical differences	1A3b	0.5	0.5	0.4	0.4
non-road consumption (models)	1A2gvii	0.0	0.0	0.0	0.0
Natural gas sold in on- and non-road categories		0.7	0.7	0.7	0.7

Table 3-43 Consumption of biofuels for road transportation. Consumption starts in 1997. Note that the unit is TJ (not PJ) and that Vegetable/Waste oil is included in the numbers of Biodiesel.

Biofuels	1990-1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
	TJ																	
Biodiesel	0	57	51	48	60	64.3	60.2	81.5	117.4	226.0	317.7	386.1	424.3	322.4	367.4	365.2	421.8	393.4
Bioethanol	0	0	0	0	0	0.0	0.0	0.0	0.0	19.0	22.3	67.1	69.2	30.3	54.6	85.2	97.3	84.3
Biogas	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	30.2	30.8	32.1	50.7	105.9	161.1	216.3
Sum	0	57.2	51.4	48.3	59.6	64.3	60.2	81.5	117.4	244.9	340.0	483.4	524.2	384.8	472.8	556.3	680.2	694.1
Share of total fuel consump. 1A3b	0.0%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.4%	0.6%	1.3%	1.8%	2.5%	2.7%	2.0%	2.4%	2.9%	3.6%	3.7%

ii) Mileage-related activity data (basis for modelling of the non-CO_2 emissions by means of a traffic model)

The activity data is derived from different data sources:

- Vehicle stock: The federal vehicle registration database MOFIS (run by the Federal Roads Office FEDRO) contains vehicle stock data including all parameters needed for the emission modelling (vehicle category, engine capacity, fuel type, total weight, vehicle age and exhaust technology). The data is not public, but the ordinary vehicle stock numbers are published by the Swiss Federal Statistical Office (SFSO 2015). The stock numbers from MOFIS are used for 1990-2010, whereas for 2011-2013 numbers are provided from a vehicle fleet projection by Prognos (2012a). With the help of a fleet turnover model the vehicle categories are split up into “sub-segments”, which are used to link with the specific emission factors of the same categorisation (vehicle category, size class, fuel type, emission standard [“Euro classes”], see also INFRAS 2010).
- The transport performance, i.e. the mileage is calculated from the specific mileage per vehicle category (based on surveys/Mikrozensus ARE/SFSO 2005) times the number of vehicles. This figure is calibrated to the official statistics of traffic performance (SFSO 2009c and SFSO 2010c)[8].
- Numbers of starts/stops: Derived from vehicles stock, with data on trip length distributions and parking time distributions (ARE/SFSO 2005).

The transport performance is attributed to “traffic situations” (characteristic patterns of driving behaviour) which serve as a key to select the appropriate emission factor which are also available per traffic situation. The relative shares of the traffic situations is derived from a national road traffic model (operated by the Federal Office of Spatial Development, see ARE 2010). The traffic model is based on an origin-destination matrix that is assigned to a network of about 20’000 road segments. The model is calibrated partly bottom-up and partly top-down: bottom-up by a number of traffic counts from the national traffic-counter network (395 stations all over Switzerland, FEDRO 2010), and top-down by the total of the mileage per vehicle category. Furthermore, it supplies all the attributes needed for assigning a “traffic situation” to each road segment. The traffic model in combination with consumption factors

[8] As reported in the NIR of submission 2014 (FOEN 2014), a recalibration of the mileage per vehicle category has been performed based on the latest figures on population growth and economy (Prognos 2012a, ARE 2012). As a result vehicle kilometres from 1993 onwards were slightly lower in total; fleet compositions have changed, with slight impacts on implied emission factors; also fuel consumption in fuel tourism was slightly reduced; the modelled share of biofuels has been reduced to be consistent with real-world developments. However the overall impacts of these revisions on emissions have been minor.

(per vehicle category, size class, fuel type, emission standard and per traffic situation) allows to calculate the **territorial** road traffic consumption of gasoline and diesel oil.

Due to fuel price differences in the vicinity of the national borders, gasoline stations sell relevant amounts of gasoline to foreign car owners. This amount of fuel is mainly consumed abroad, called **fuel tourism**, but the whole amount must be reported to UNFCCC as national under 1A3b Road Transportation. For the CO_2 emissions, the amount of fuel tourism is irrelevant since it is included in the sales principle; the non-CO_2 emissions related to the fuel tourism, however, are not captured by the traffic model. For the purpose of assuring completeness within the GHG inventory, these emissions are quantified on the basis of the difference between fuel consumption according to the Swiss overall energy statistics (sales principle) and fuel consumption derived from the traffic model (territorial). The resulting amount of fuel, given as “fuel tourism an statistical differences[9]” in Table 3-42, is multiplied with mean emission factors to determine the related emissions of CH_4, N_2O, NO_x, CO, NMVOC, and SO_2. For CO_2, which dominates the emissions by a factor of approx. 1’000-10’000, the use of Swiss mean factors is correct, since the carbon content constitutes the emission factor. For CH_4 and N_2O there are differences between the Swiss mean factors and the implied emission factors of the four neighbouring countries Austria, France, Germany, Italy, as a comparison with their implied emission factors for 1990 and 2004 has shown. The differences are small between Switzerland, Austria, and Germany because all three countries use the same emission factors (SAEFL 2004a, INFRAS 2010, INFRAS 2011), whereas there are some differences when compared to France and Italy that use other emission factors (COPERT[10]). Nevertheless, the use of the mean Swiss emission factors seems to be the consistent approach.

Table 3-44 shows the time series of the mileage per vehicle category. In 2013, 86.1% of total vehicle kilometres are driven by passenger cars, 5.8% and 3.6% by light and heavy duty vehicles, respectively. The mileages increased for all vehicle categories (except coaches) by 29.4% in the period 1990–2013. In the same period, fuel consumption increased less strongly, by 14%, indicating improved fuel efficiency. This effect is also reflected in Table 3-45 that depicts the specific fuel consumption per vehicle-km. For most vehicle categories, the specific consumption has decreased in the period 1990-2013 (between 1% and 24%). Consumption of light duty vehicles remained indifferent while two-wheelers have increased their average specific consumption by 20%. Concerning the whole car fleet, a decrease of 16% in specific consumption has been reached between 1990 and 2013.

---

[9] The amount of fuel tourism has been estimated by SFOE (2010). The result shows that the difference between fuels sales and fuels determined by the traffic model tend to overestimate the “true” fuel tourism. It is concluded that the difference also contains potential underestimation of the mileage and other statistical errors. The difference is therefore indicated in the NIR as “fuel tourism and statistical differences”.

[10] see Euopean Environment Agency http://www.eea.europa.eu/publications/TEC05 [26.02.2015]

Table 3-44 Mileages in millions of vehicle kilometres. PC: passenger cars, LDV: light duty vehicles, HDV: heavy duty vehicles).

Veh. category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	million vehicle-km									
PC	42'650	43'745	43'178	42'259	43'199	43'824	44'063	44'675	45'570	46'702
LDV	2'758	2'742	2'867	2'632	2'669	2'746	2'767	2'786	2'831	2'903
HDV	1'992	2'015	2'036	2'025	2'109	2'107	2'055	2'072	2'126	2'200
Coaches	108	108	109	109	110	110	109	108	101	98
Urban Bus	174	186	188	190	190	192	188	188	192	195
2-Wheelers	2'025	1'947	1'866	1'792	1'717	1'744	1'756	1'823	1'872	1'941
Sum	49'707	50'743	50'244	49'007	49'993	50'724	50'939	51'653	52'692	54'039
(1990=100%)	100%	102%	101%	99%	101%	102%	102%	104%	106%	109%

Veh. category	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	million vehicle-km									
PC	48'063	48'509	49'062	49'527	50'019	50'465	50'812	51'208	51'949	52'852
LDV	2'978	3'059	3'119	3'149	3'215	3'300	3'374	3'473	3'529	3'584
HDV	2'273	2'165	2'109	2'115	2'144	2'127	2'189	2'203	2'223	2'172
Coaches	99	95	93	95	98	106	118	120	114	119
Urban Bus	200	205	211	215	220	229	233	240	245	249
2-Wheelers	1'999	2'048	2'098	2'152	2'190	2'204	2'262	2'300	2'366	2'385
Sum	55'612	56'082	56'693	57'253	57'886	58'432	58'989	59'544	60'426	61'361
(1990=100%)	112%	113%	114%	115%	116%	118%	119%	120%	122%	123%

Veh. category	2010	2011	2012	2013
	million vehicle-km			
PC	53'341	54'000	54'730	55'424
LDV	3'621	3'663	3'701	3'735
HDV	2'210	2'250	2'290	2'329
Coaches	119	119	118	118
Urban Bus	251	254	257	261
2-Wheelers	2'407	2'436	2'465	2'494
Sum	61'950	62'722	63'562	64'362
(1990=100%)	125%	126%	128%	129%

Table 3-45 Specific fuel consumption of road transport, not including fuel tourism and statistical differences (PC: passenger cars, LDV: light duty vehicles, HDV: heavy duty vehicles).

Veh. cat.	Fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
		specific fuel consumption (MJ/veh-km)									
PC	Gasoline	3.18	3.20	3.22	3.23	3.23	3.23	3.22	3.21	3.19	3.17
	Diesel	2.91	2.91	2.92	2.98	2.90	2.90	2.90	2.91	2.89	2.86
	CNG										
LDV	Gasoline	3.17	3.18	3.17	3.18	3.18	3.18	3.18	3.17	3.17	3.18
	Diesel	3.86	3.87	3.87	3.88	3.87	3.86	3.83	3.81	3.79	3.77
HDV	Diesel	10.91	10.95	10.98	10.92	10.97	10.85	10.71	10.58	10.46	10.38
Coach	Diesel	11.84	11.85	11.87	11.81	11.75	11.69	11.62	11.55	11.48	11.42
Urban Bus	Diesel	16.22	16.29	16.33	16.34	16.32	16.29	16.20	16.10	16.02	15.90
	CNG										
2-Wheeler	Gasoline	1.11	1.14	1.17	1.19	1.21	1.22	1.22	1.24	1.24	1.24
Average		**3.46**	**3.49**	**3.52**	**3.54**	**3.55**	**3.54**	**3.51**	**3.49**	**3.47**	**3.44**
		100%	**101%**	**101%**	**102%**	**102%**	**102%**	**101%**	**101%**	**100%**	**99%**

Veh. cat.	Fuel	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
		specific fuel consumption (MJ/veh-km)									
PC	Gasoline	3.14	3.13	3.11	3.09	3.06	3.04	2.99	2.97	2.93	2.90
	Diesel	2.80	2.72	2.66	2.58	2.52	2.46	2.41	2.40	2.35	2.33
	CNG								2.91	2.88	2.85
LDV	Gasoline	3.18	3.17	3.18	3.19	3.19	3.19	3.21	3.21	3.20	3.19
	Diesel	3.75	3.71	3.63	3.56	3.48	3.42	3.37	3.34	3.32	3.31
HDV	Diesel	10.33	10.56	10.62	10.63	10.61	10.77	10.71	10.73	10.65	10.59
Coach	Diesel	11.33	11.25	11.21	11.19	11.21	11.22	11.23	11.22	11.18	11.16
Urban Bus	Diesel	15.80	15.71	15.60	15.45	15.45	15.37	15.24	15.23	15.05	14.94
	CNG								20.34	20.32	20.36
2-Wheeler	Gasoline	1.25	1.25	1.24	1.25	1.27	1.28	1.29	1.31	1.33	1.35
Average		**3.42**	**3.39**	**3.35**	**3.32**	**3.28**	**3.24**	**3.20**	**3.17**	**3.12**	**3.07**
		99%	**98%**	**97%**	**96%**	**95%**	**94%**	**92%**	**91%**	**90%**	**89%**

Veh. cat.	Fuel	2010	2011	2012	2013
		MJ/veh-km			
PC	Gasoline	2.86	2.81	2.77	2.71
	Diesel	2.30	2.28	2.24	2.21
	CNG	2.83	2.53	2.51	2.49
LDV	Gasoline	3.18	3.17	3.15	3.13
	Diesel	3.31	3.30	3.29	3.26
HDV	Diesel	10.55	10.50	10.46	10.41
Coach	Diesel	11.16	11.15	11.14	11.12
Urban Bus	Diesel	14.81	14.76	14.72	14.68
	CNG	20.58	20.52	20.46	20.38
2-Wheeler	Gasoline	1.34	1.34	1.34	1.34
Average		**3.03**	**2.99**	**2.94**	**2.89**
		87%	**86%**	**85%**	**84%**

For modelling of cold start and evaporative emissions of passenger cars and light duty vehicles, also vehicle stock and start numbers are used for activity data. The corresponding numbers are summarised in Table 3-46. Vehicle stock figures correspond to registration data. The starts per vehicle are based on specific surveys (ARE/SFSO 2005).

Table 3-46 Vehicle stock numbers and average number of starts per vehicle per day (PC: passenger cars, LDV: light duty vehicles).

Veh. Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	stock in 1000 vehicles									
PC	2'985	3'058	3'091	3'110	3'165	3'229	3'268	3'323	3'383	3'467
LDV	221	228	229	228	232	238	241	243	247	254
2-Wheelers	764	747	729	720	708	704	699	709	718	728
	starts per vehicle per day									
PC	2.61	2.60	2.58	2.56	2.54	2.53	2.53	2.51	2.49	2.47
LDV	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97
2-Wheelers	1.59	1.58	1.57	1.56	1.55	1.54	1.54	1.53	1.52	1.51

Veh. Category	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	stock in 1000 vehicles									
PC	3'545	3'630	3'701	3'754	3'811	3'862	3'894	3'956	3'990	4'010
LDV	260	268	274	278	284	291	298	307	312	317
2-Wheelers	732	740	753	763	771	770	784	789	804	807
	starts per vehicle per day									
PC	2.46	2.45	2.44	2.43	2.41	2.40	2.39	2.38	2.37	2.35
LDV	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96
2-Wheelers	1.50	1.51	1.52	1.52	1.53	1.54	1.54	1.55	1.56	1.56

Veh. Category	2010	2011	2012	2013
	stock in 1000 vehicles			
PC	4'076	4'195	4'302	4'396
LDV	326	328	331	334
2-Wheelers	816	815	815	816
	starts per vehicle per day			
PC	2.34	2.34	2.33	2.33
LDV	1.96	1.96	1.96	1.96
2-Wheelers	1.57	1.57	1.57	1.58

c) Railways (1A3c)

Methodology

The entire Swiss railway system is electrified. Electric locomotives are used in passenger as well as freight railway traffic. Diesel locomotives are used for shunting purposes in marshalling yards and for construction activities only.

Emissions of diesel rail vehicles are calculated using the non-road model developed by INFRAS (2008). For details refer to Chapter 3.2.4.1.2 and 3.2.4.1.3) Mobile (1A2gvii).

Emission Factors

Only diesel oil is being used as fuel, therefore all emission factors refer to diesel oil.

- The emission factor for CO_2 is country-specific with value 73.3 t/TJ in 2013 (diesel oil, see Table 3-11, SFOE/FOEN 2014).
- For SO_2 the emission factors are country-specific. They are depicted in Table A-29 in Annex 3.1.5, row diesel oil.
- The emission factors for all other gases are country-specific and are shown in in Annex A3.1.4, Table A - 22. Note that NMVOC is not modelled bottom-up. The NMVOC emissions are calculated to be the difference of VOC and CH_4 emissions. Note that emission factors in the unit of kg/h may be downloaded by query from the public part of the non-road database (INFRAS 2008).

Activity Data

The fuel consumption is calculated in the same way as emission modelling but using fuel consumption factors instead of emission factors (see Table A - 22). The operating hours depend on the number of vehicles per age and size class. In 2005 e.g., 1'255 vehicles were operating 0.77 million hours per year with an average number of 616 operating hours per year per vehicle, see Tables A-27 and A-28 (INFRAS 2008). As mentioned above, a slight update was carried out in 2013 based on the latest figures on population and economy (Prognos 2012a). The diesel consumption has been recalculated accordingly. Numbers from 2005 onwards are affected. The resulting fuel consumption is shown in Table 3-47.

Table 3-47 Activity data (diesel oil consumption) for railways.

1A3c Railways	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Diesel	TJ	390	400	410	420	430	441	443	446	449	452
1990=100%		100.0%	102.6%	105.2%	107.8%	110.4%	113.0%	113.8%	114.5%	115.2%	116.0%

1A3c Railways	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Diesel	TJ	455	460	466	472	477	483	494	504	515	526
1990=100%		116.7%	118.1%	119.6%	121.0%	122.4%	123.8%	126.6%	129.4%	132.2%	135.0%

1A3c Railways	Unit	2010	2011	2012	2013
Diesel	TJ	537	538	539	540
1990=100%		137.8%	138.1%	138.3%	138.6%

d) Domestic navigation (1A3d)

Methodology

There are passenger ships, dredgers, fishing boats, motor and sailing boats on the lakes and rivers in Switzerland. Every boat is registered with the cantonal authorities.

Emissions of ships and boats are calculated using the non-road model developed by INFRAS (2008). For details refer to Chapter 3.2.4.1.2, paragraph ii) Mobile (1A2gvii).

On the river Rhine as well as on the lake Geneva and lake Constance, some of the boats cross the border. Fuels bought in Switzerland but used for international navigation are therefore reported as bunker fuels (Section 3.2.2.)

Emission Factors

- The emission factor for CO_2 is country-specific and interpolated in the period 1998-2013 and assumed constant in the years before. In 2013, the CO_2 EF is 73.3 t/TJ for diesel oil, 73.8 t/TJ for gasoline, and 73.7 t/TJ for gas oil (Table 3-11, Table 3-12)
- For SO_2 the emission factors are country-specific and are given in Table A – 29 in Annex 3.1.5 (diesel oil, gasoline, gas oil).
- The emission factors for all other gases are country-specific and are shown in Table A-23 to Table A – 26 in Annex A3.1.4. Note that NMVOC is not modelled bottom-up. The NMVOC emissions are calculated as the difference of VOC and CH_4 emissions.

Note that emission factors in the unit of kg/h may be downloaded by query from the public part of the non-road database INFRAS (2008).

Activity Data

The numbers of vehicles and of operating hours are given in Annex A3.1.4, Tables A-27 and A-28 (INFRAS 2008). Table 3-48 shows the domestic fuel consumption. In 2013, the fuel-split was 52%, 38% and 10% for diesel oil, gasoline and gas oil.

Table 3-48 Fuel consumption of (domestic) navigation.

1A3d Navigation	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Diesel	TJ	705	703	701	698	696	694	708	723	737	752
Gasoline	TJ	701	692	683	673	664	654	647	639	631	623
Gas oil	TJ	111	117	122	128	134	140	141	143	145	146
Sum	TJ	1'518	1'512	1'506	1'500	1'494	1'488	1'496	1'505	1'513	1'522
1990 = 100%		100%	100%	99%	99%	98%	98%	99%	99%	100%	100%

1A3d Navigation	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Diesel	TJ	766	770	774	778	782	786	800	815	830	844
Gasoline	TJ	616	614	613	612	611	609	615	620	626	631
Gas oil	TJ	148	150	153	156	158	161	162	164	166	167
Sum	TJ	1'530	1'535	1'540	1'546	1'551	1'556	1'578	1'599	1'621	1'643
1990 = 100%		101%	101%	101%	102%	102%	103%	104%	105%	107%	108%

1A3d Navigation	Unit	2010	2011	2012	2013
Diesel	TJ	859	853	847	841
Gasoline	TJ	637	632	626	621
Gas oil	TJ	169	169	170	170
Sum	TJ	1'665	1'654	1'643	1'632
1990 = 100%		110%	109%	108%	108%

e) Other Transportation (1A3e)

Methodology

Source 1A3e includes only pipeline transportation (1A3e i). Emissions of CO_2, CH_4, N_2O, NO_x, CO, NMVOC and SO_2 stem from a compressor station located in Ruswil. The compressor station uses a centrifugal compressor according to Transitgas AG (the company operating the compressor station and the pipeline network). The emissions are calculated with a Tier 2 method by multiplying country-specific emission factors with activity data.

Emission Factors

Annual CO_2 emission factors in 1A3e are country-specific (see Table 3-12 in 3.2.4.2) and based on measurements of gas properties and corresponding import shares of individual gas import stations. The CH_4 emission factor corresponds to the one used for gas turbines in Switzerland (SAEFL 2000) as suggested by expert judgement (see also Battelle 1994 and Xinmin 2004). The CH_4 EF is assumed to be 5 g/GJ up to 1995 and 2 g/GJ from 2000 onwards, with linear interpolation in between. This corresponds with the fact that a catalyst was fitted to the system, which reduced the CH_4 emissions of the gas turbine. For N_2O emission factors the IPCC 2006 default value (0.1g/GJ) is used as displayed in Table 3-15.

Activity Data

The data on fuel consumption for the operation of the compressor station in Ruswil is based on the Swiss overall energy statistics (SFOE 2014), see also Figure 3-10.

3.2.7.3 Uncertainties and Time-Series Consistency

For a general description of the uncertainty analysis and time series consistency of the Energy sector see chapter 3.2.4.4 where uncertainties of activity data and of CO_2 emission factors of fuels are shown (Table 3-19).

Uncertainties of non-CO_2 gases: Following a study for the road transportation in Germany (IFEU/INFRAS 2009), where the same handbook of emission factors is used as in Switzerland, the uncertainties for the CH_4 and N_2O emission factors have been determined:

- CH_4: 37% (gasoline) and 20% (diesel),
- N_2O: 50% (gasoline) and 22% (diesel).

For the CH_4 emissions of CNG the qualitative uncertainty “medium” (30%) is taken and for biomass the uncertainty "high" (60%) according to Table 1-11.

For the N_2O emissions of CNG the qualitative uncertainty “medium” (80%) is taken and for biomass the uncertainty "high" (150%) according to Table 1-11.

Consistency: Time series for 1A3 Transport are all considered consistent.

3.2.7.4 Category-specific QA/QC and Verification

a) General

The general QA/QC measures are described in section 1.2.3 and partly also in chapter 3.2.4.5.

b) Specific: Domestic Aviation (1A3a)

Emissions

Total calculated emissions for domestic and international flights have been compared between different years. The development of total emissions with time is consistent with a fleet renewal of former Swissair in the early nineties, the technological improvements and changes in fleet composition.

Emission factors

- From total fuel burnt, total distance, number of passenger (without freight) per aircraft type, the fuel consumption per 100 passenger km has been calculated (backward calculation). The result of 2 to 10 kg fuel/100 passenger km is in line with expectations for 1990 passenger fleets.

- The implied emission factors were calculated for 2013 and compared with previous years.

Activity data

- In an independent Tier 3b calculation, EUROCONTROL performed a fuel calculation for Switzerland's international flights, based on collected flight plan data and single movements. The results for the years 2004, 2005 and 2007 matched the FOCA calculations by more than 97.4%. The FOCA results were generally 1% to 2% higher but included the total number of actual flight movements of all flights, including VFR (visual flight rules) and non-scheduled flights such as helicopter movements in alpine regions.
- Comparison between total movement numbers in the calculation and in the corresponding published statistics. Example: In 1990 calculation, FOCA considered all flights for which there was a form 'Traffic report to the airport authorities' filled in (total heavy aircraft). The total number of movements in 1990 is 263'951 (without Basel). The published number of movements for scheduled and charter flights in 1990 is: 263'952 (without Basel).
- The bottom-up calculation of total fuel matches the total fuel sold within a few percent's.
- Real-world fuel consumption was compared with modelled consumption for selected aircrafts of four Swiss airlines. The difference between the two methods was smaller than 1%.

c) Specific: Road Transportation (1A3b)

Comparison between 2006 IPCC Guidelines default and Switzerland's emission factors:

- CO_2 (see also Table 3-20): IPCC default value for gasoline is 69.3 t/TJ and for diesel oil 74.1 t/TJ (IPCC 2006, Table 3.2.1). Switzerland's emission factors vary between 73.8 and 73.9 t/TJ for gasoline – 6% higher than IPCC – and between 73.3 and 73.6 t/TJ for diesel oil – about 1% below IPCC default value.
- CH_4: The IPCC default emission factor for gasoline motors with oxidation catalysts is 25 kg/TJ with an uncertainty range from 7.5 to 86 kg/TJ (IPCC 2006, Table 3.2.2). Switzerland's emission factor for gasoline passenger cars dropped from 26.6 kg/TJ (1990) to 5.5 kg/TJ (2013) and is therefore in the lower part of IPCC's uncertainty range. For diesel oil the IPCC default emission factors lies in the range of 1.6-9.5 kg/TJ, whereas Switzerland's range is lower 0.3-1.5 kg/TJ.
- N_2O: The IPCC default emission factor for gasoline motors with oxidation catalysts lies in the uncertainty range 2.6-24 kg/TJ (IPCC 2006, Table 3.2.2). Switzerland's emission factor for gasoline passenger cars dropped from 3.1 kg/TJ (1990) to 0.6 kg/TJ (2013) and is therefore in the lower part of and below IPCC's uncertainty range. For diesel oil the IPCC default emission factors lies in the range of 1.3-12 kg/TJ, whereas Switzerland's range is lower 0.2-2.2 kg/TJ.

The international project for the update of the emission factors for road vehicles is overseen by a group of external and international experts that guarantees an independent quality control. For the update of the modelling of Switzerland's road transport emissions, which has been carried out between 2008 and 2010, several experts from the federal administration have conducted the project. The results have undergone large plausibility checks and comparisons with earlier estimates.

The emission factors CH_4 and N_2O used for the modelling of 1A3b Road Transportation are taken from the handbook of emission factors (INFRAS 2010), which is also applied in Germany, Austria, Netherlands, and Sweden. The Swiss emission factors for CH_4 and N_2O used in 1A3b were additionally compared with those depicted in the CRF from Germany and a good match was found. Possible small differences might result from a varying fleet composition.

For gasoline, the activity data is easily verified due to the fact, that 94% of the gasoline sold 2013 in Switzerland is consumed by 1A3b Road Transportation itself. Therefore the amount of gasoline reported in the Swiss overall energy statistics is a strong control and verification parameter for the activity data of 1A3b. For diesel, the same control is carried out and the amount of diesel consumed by 1A3b Road Transportation is 82% compared to the amount sold in 2013.

3.2.7.5 Category-specific Recalculations

- 1A3b: New calorific values and CO_2 emission factors for gasoline, diesel, gas oil and kerosene based on new measurements for the year 2013. The emission factors are assumed constant for the period 1990-1998, and interpolated between 1998-2013 (see Table 3-11 in chapter 3.2.4.2).
- 1A3b: For source category Fuel tourism and statistical differences, the emission factors of all GHG have been recalculated due to the model revision for the entire time series 1980-2050.
- 1A3b: Since a small change occurred in the gasoline consumption in Liechtenstein for 2001-2011, small changes in the activity data for Fuel tourism and statistical differences resulted in Switzerland.

3.2.7.6 Category-specific Planned Improvements

For submission 2016 the consideration of the revised non-road model is envisaged.

3.2.8 Source Category 1A4 - Other Sectors (Commercial/Institutional, Residential, Agriculture/Forestry/Fishing)

3.2.8.1 Source Category Description

Approach 1 Key categories 1A4

CO_2 from the combustion of Liquid Fuels in the Commercial/Institutional Sector (level and trend)
CO_2 from the combustion of Gaseous Fuels in the Commercial/Institutional Sector (level and trend)
CO_2 from the combustion of Liquid Fuels in the Residential Sector (level and trend)
CO_2 from the combustion of Gaseous Fuels in the Residential Sector (level and trend)
CO_2 from the combustion of Liquid Fuels in the Agriculture/Forestry/Fishing Sector (level)

Approach 2 Key categories 1A4

CO_2 from the combustion of Gaseous Fuels in the Commercial/Institutional Sector (level and trend)
CO_2 from the combustion of Gaseous Fuels in the Residential Sector (level and trend)

CH_4 from the combustion of Biomass in the Residential Sector (trend)

Table 3-49 Specification of source category 1A4 Other sectors.
EMIS 2015/… refers to the internal documentation of the emission database and contains further references regarding specific AD and/or EF.

1A4	Source	Specification	Data Source
1A4a	Commercial/ Institutional	Emission from stationary fuel combustion in commercial and institutional buildings (1A4ai) and from mobile non-road machinery (professional gardening) and motorised equipment (1A4aii)	AD: SFOE 2014, INFRAS 2008, Prognos 2012, Keller/INFRAS 2013, EMIS 2015/1A4div_nonroad. EF: EMPA 1999; SFOE/FOEN 2014; FOEN 2015d; IPCC 2006; EMIS 2015/1A Holzfeuerungen; SAEFL 2000; Nussbaumer and Hälg 2015; EMIS 2015/1A4a, INFRAS 2008, EMIS 2015/1A4div_nonroad.
1A4b	Residential	Emissions from stationary fuel combustion in households (1A4bi) and from mobile machinery (hobby gardening) and motorised equipment (1A4bii)	AD: SFOE 2014, INFRAS 2008, Prognos 2012, Keller/INFRAS 2013, EMIS 2014/1A4div. EF: EMPA 1999; SFOE/FOEN 2014; FOEN 2011k; IPCC 2006; EMIS 2014/1A Holzfeuerungen; SAEFL 2000; Nussbaumer and Hälg 2015; EMIS 2015/1A4b INFRAS 2008, EMIS 2015/1A4div_nonroad
1A4c	Agriculture/ Forestry/ Fishing	Comprises stationary fuel combustion for heating in forestry and agriculture and grass drying (1A4ci) and mobile machinery (non-road) in agriculture and forestry as well as professional fishery boats (1A4cii)	AD and EF: EMIS 2015/1A4ci Grasstrocknung AD: Non-road machinery: INFRAS 2008, Prognos 2012, Keller/INFRAS 2013

3.2.8.2 Methodological Issues

As explained in chapter 3.2.4, a country-specific Tier 2 approach based on aggregated fuel consumption data from the Swiss overall energy statistics is used to calculate emissions (SFOE 2014). Source category 1A4b also includes charcoal use and bonfires in Switzerland.

Emissions of GHGs are calculated by multiplying levels of activity by emission factors.

For mobile non-road sources (1A4aii, 1A4bii and 1A4cii) the emissions are calculated by the same approach as all other non-road categories using the non-road model developed by INFRAS (2008). For details refer to Chapter 3.2.4.1.2 (paragraph on source category 1A2g).

Emission Factors

The following table presents the emission factors used in 1A4a/b:

Table 3-50 Emission Factors for stationary combustion in 1A4a Other Sectors Commercial/Institutional and 1A4b Residential in 2013.

Source/fuel	CO_2	CO_2 biog.	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
	t/TJ		kg/TJ					
1A4a Other sectors: Commercial/institutional								
Gas oil (weighted average)	73.7		1.0	0.6	35	6.8	6.0	21
Gas oil (heat only boilers)	73.7		1.0	0.6	35	6.7	6.0	21
Gas oil (turbines)	NO		NO	NO	NO	NO	NO	NO
Gas oil (engines)	73.7		0.6	0.6	40	30	8.0	20
Natural gas (weighted average)	56.4		6.8	0.1	24	13	3.8	0.5
NG (heat only boilers)	56.4		6.0	0.1	18	10	4.0	0.5
NG (turbines)	56.4		2.0	0.1	60	15	0.1	0.5
NG (engines)	56.4		20	0.1	115	58	1.0	0.5
Other bituminous coal	NO		NO	NO	NO	NO	NO	NO
Lignite	NO		NO	NO	NO	NO	NO	NO
Biomass (weighted average)		87.5	20	3.5	109	647	29	18
Biomass (wood)		92.0	22	4.0	122	740	33	20
Biomass (biogas)		56.4	6.0	0.1	18	10	2.0	0.5
Gasoline (gardening professional)	73.8		90	2.2	161	23'582	2'088	0.4
1A4b Other sectors: Residential								
Gas oil (weighted average)	73.7		1.0	0.6	37	12	6.0	21
Gas oil (heat only boilers)	73.7		1.0	0.6	37	12	6.0	21
Gas oil (turbines)	NO		NO	NO	NO	NO	NO	NO
Gas oil (engines)	73.7		2.0	0.6	40	30	8.0	20
Natural gas (weighted average)	56.4		6.1	0.1	17	14	4.0	0.5
NG (heat only boilers)	56.4		6.0	0.1	17	13	4.0	0.5
NG (turbines)	56.4		2.0	0.1	60	15	0.1	0.5
NG (engines)	56.4		20	0.1	36	58	1.0	0.5
Other bituminous coal	92.7		300	1.6	65	2'000	100	350
Lignite	NO		NO	NO	NO	NO	NO	NO
Biomass		92.3	63	4.0	91	1'679	119	20
Gasoline (gardening)	73.8		53	2.5	156	24'470	1'509	0.4

Emission factors for CO_2, CH_4 and N_2O of charcoal use in the residential sector (1A4bi) are based on the 2006 IPCC guidelines. For emission factors N_2O of wood combustion the default value from the 2006 IPCC guidelines is applied. CO_2 emission factor for bonfires in the residential sector (1A4bi) is based on SAEFL 2000 and CH_4 and N_2O emission factors are based on 2006 IPCC guidelines.

Table 3-51 Emission Factors for 1A4a/b Other Sectors Commercial/Institutional and Residential in 2013. The CO_2 emission factor is biogenic. For precursors the values from the EMEP/EEA Guidebook (2009) are applied.

1A4bi Residential: Stationary combustion	Unit	CO_2 biog.	CH_4	N_2O	Nox	CO	NMVOC	SO_2
Use of charcoal	kg/TJ	112'000	200	4	50	6'000	1'300	10
Bonfires	kg/TJ	92'000	300	4	50	6'000	1'300	10

Emission factors for mobile non-road sources

- The emission factors for CO2 are country-specific and interpolated in the period 1998-2013 with 2012 values 73.3 t/TJ for diesel oil, 73.8 t/TJ for gasoline and 56.4 t/TJ for CNG. See Table 3-11 and Table 3-12) Before 1998 the EF are assumed to be constant.
- For SO_2 the emission factors are country-specific and are given in Table A - 29 in Annex 3.1.5.
- The emission factors for all other gases are country-specific and shown in Table A – 18 to Table A - 21in the Annex A3.1.4 (INFRAS 2008). The NMVOC emissions are calculated as the difference of VOC and CH_4 emissions.

Note that emission factors in the unit of kg/h may be downloaded by query from the public part of the non-road database INFRAS (2008).

Activity Data

Activity data for the different fuels are derived as described in chapter 3.2.4.1. This includes gas oil, residual fuel oil, natural gas and biomass. For other bituminous coal, activity data is provided directly by the Swiss overall energy statistics (SFOE 2014).

Table 3-52 documents the use of gas oil (55%), natural gas (35%) and biomass (10%) as fuels consumed in source category 1A4a Commercial/Institutional. Since 1990, fuel consumption in category 1A4a increased by 3%, within a pronounced shift from gas oil to natural gas and biomass consumption. Gas oil consumption decreased by 23%, while natural gas and biomass consumption increased by 59% and 178% respectively.

Similar to source category 1A4a, the major fuels consumed in source category 1A4b Residential are gas oil (58%), natural gas (30%) and biomass (12%). Since 1990, fuel consumption in the residential sector decreased by 8%. Also in this source category, a shift from gas oil (-27%) to natural gas (+97%) can be observed, whereas biomass consumption diminished from 1990 to 2013 by 8%.

This change in fuel mix is the reason for CO_2 emissions from the use of natural gas and liquid fuels in category 1A4a and 1A4b being key categories regarding trend.

Charcoal is only used for charcoal grills, therefore its consumption is very small compared to other fuels used for room heating. Charcoal use has slightly increased from 1990 to 2009 and since 2009 a stable consumption of charcoal is assumed (SFOE 2014, see documentation in EMIS 2015/1A4bi Holzkohle-Verbrauch). As charcoal consumption is more or less constant, it is assumed, that bonfires are also constant over time, with an estimation of 2kg of wood consumption for bonfires per habitant (see documentation in EMIS 2015/1A4bi Lagerfeuer).

Table 3-52 Activity data in 1A4a Commercial/Institutional and 1A4b Residential.

Source/Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1A4a Other sectors: Commercial/institutional	TJ	78'314	88'282	89'096	90'314	82'044	85'721	93'112	84'278	90'472	84'357
Gas oil	TJ	57'604	65'576	65'333	65'422	57'354	58'798	63'928	56'182	61'156	56'362
Gas oil heat only boilers	TJ	57'580	65'525	65'275	65'366	57'232	58'623	63'697	55'894	60'858	56'035
Gas oil turbines	TJ	0	0	0	0	0	0	0	0	0	0
Gas oil engines	TJ	24	51	58	56	122	175	231	288	298	327
Natural gas	TJ	17'540	19'092	20'146	21'159	21'055	22'787	24'494	23'691	24'599	23'124
NG heat only boilers	TJ	17'264	18'657	19'586	20'533	20'233	21'617	23'083	22'225	22'996	21'414
NG turbines	TJ	85	114	109	106	107	78	21	5	12	4
NG engines	TJ	192	321	451	520	715	1'093	1'390	1'460	1'590	1'706
Other bituminous coal	TJ	0	0	0	0	0	0	0	0	0	0
Lignite	TJ	0	0	0	0	0	0	0	0	0	0
Biomass (total)	TJ	2'961	3'393	3'384	3'489	3'379	3'868	4'412	4'116	4'418	4'560
Biomass (wood)	TJ	2'937	3'369	3'360	3'457	3'345	3'834	4'373	4'076	4'370	4'512
Biomass (biogas)	TJ	24	24	24	31	34	34	40	40	48	48
Gasoline (gardening professional)	TJ	209	221	233	244	256	267	278	289	300	311
1A4b Other sectors: Residential	TJ	185'577	197'494	196'735	187'558	176'310	189'790	197'080	182'500	188'303	185'138
Gas oil	TJ	136'886	142'967	142'205	133'042	125'461	133'547	135'642	127'575	131'798	127'118
Gas oil heat only boilers	TJ	136'885	142'966	142'203	133'041	125'460	133'543	135'611	127'537	131'749	127'065
Gas oil turbines	TJ	0	0	0	0	0	0	0	0	0	0
Gas oil engines	TJ	1	1	1	1	1	4	32	38	49	53
Natural gas	TJ	25'990	29'680	31'070	31'440	29'840	34'230	38'320	34'760	36'270	38'270
NG heat only boilers	TJ	25'930	29'578	30'926	31'272	29'636	33'972	38'013	34'447	35'920	37'865
NG turbines	TJ	0	0	0	0	0	0	0	0	0	0
NG engines	TJ	60	102	144	168	204	258	307	313	350	405
Other bituminous coal	TJ	630	750	620	530	480	460	260	220	140	140
Lignite	TJ	0	0	0	0	0	0	0	0	0	0
Biomass	TJ	21'926	23'950	22'690	22'393	20'374	21'395	22'697	19'782	19'930	19'443
Gasoline (gardening)	TJ	145	147	150	153	155	158	160	162	165	167

Source/Fuel	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1A4a Other sectors: Commercial/institutional	TJ	81'972	93'141	82'697	88'143	86'578	88'040	82'879	75'072	79'324	77'278
Gas oil	TJ	53'004	62'483	53'215	56'970	54'482	54'919	51'536	45'433	47'569	45'683
Gas oil heat only boilers	TJ	52'653	62'116	52'864	56'637	54'157	54'602	51'243	45'251	47'400	45'529
Gas oil turbines	TJ	0	0	0	0	0	0	0	0	0	0
Gas oil engines	TJ	351	367	352	333	326	318	293	181	169	154
Natural gas	TJ	24'291	25'610	24'570	25'824	26'635	27'484	25'070	23'540	25'008	24'511
NG heat only boilers	TJ	22'554	23'805	22'659	23'827	24'667	25'451	23'118	21'613	23'150	22'697
NG turbines	TJ	0	3	12	28	31	28	23	28	29	26
NG engines	TJ	1'737	1'803	1'899	1'968	1'937	2'004	1'929	1'898	1'829	1'787
Other bituminous coal	TJ	0	0	0	0	0	0	0	0	0	0
Lignite	TJ	0	0	0	0	0	0	0	0	0	0
Biomass (total)	TJ	4'356	4'733	4'604	5'049	5'166	5'349	5'986	5'813	6'461	6'799
Biomass (wood)	TJ	4'300	4'666	4'533	4'965	5'065	5'203	5'769	5'499	6'030	6'299
Biomass (biogas)	TJ	56	68	71	83	101	146	217	314	432	500
Gasoline (gardening professional)	TJ	321	315	308	301	295	288	287	286	286	285
1A4b Other sectors: Residential	TJ	170'650	179'631	173'068	182'918	182'924	185'977	178'919	159'336	170'547	167'037
Gas oil	TJ	116'294	122'673	117'620	124'058	122'814	124'023	118'885	102'728	108'715	105'295
Gas oil heat only boilers	TJ	116'241	122'618	117'564	123'999	122'739	123'960	118'822	102'663	108'663	105'254
Gas oil turbines	TJ	0	0	0	0	0	0	0	0	0	0
Gas oil engines	TJ	53	55	56	58	74	63	63	65	52	42
Natural gas	TJ	36'430	38'080	37'790	40'330	41'660	42'790	41'080	39'320	42'550	42'630
NG heat only boilers	TJ	35'991	37'619	37'325	39'813	41'153	42'260	40'538	38'775	42'009	42'092
NG turbines	TJ	0	0	5	3	2	0	0	3	3	0
NG engines	TJ	439	461	460	514	505	530	542	542	537	538
Other bituminous coal	TJ	130	130	130	130	400	400	400	400	400	400
Lignite	TJ	0	0	0	0	0	0	0	0	0	0
Biomass	TJ	17'627	18'582	17'364	18'238	17'890	18'606	18'397	16'732	18'727	18'557
Gasoline (gardening)	TJ	169	167	165	162	160	158	157	156	155	155

Source/Fuel	Unit	2010	2011	2012	2013
1A4a Other sectors: Commercial/institutional	TJ	83'606	68'471	75'372	80'697
Gas oil	TJ	48'762	38'884	41'795	44'312
Gas oil heat only boilers	TJ	48'640	38'772	41'693	44'210
Gas oil turbines	TJ	0	0	0	0
Gas oil engines	TJ	122	111	103	103
Natural gas	TJ	27'213	22'952	25'972	27'879
NG heat only boilers	TJ	25'460	21'278	24'279	26'186
NG turbines	TJ	23	17	5	5
NG engines	TJ	1'730	1'657	1'688	1'688
Other bituminous coal	TJ	0	0	0	0
Lignite	TJ	0	0	0	0
Biomass (total)	TJ	7'346	6'355	7'328	8'231
Biomass (wood)	TJ	6'700	5'623	6'502	7'181
Biomass (biogas)	TJ	646	732	826	1'051
Gasoline (gardening professional)	TJ	284	281	277	274
1A4b Other sectors: Residential	TJ	180'951	145'391	160'357	171'444
Gas oil	TJ	111'731	86'988	94'103	99'373
Gas oil heat only boilers	TJ	111'694	86'953	94'068	99'339
Gas oil turbines	TJ	0	0	0	0
Gas oil engines	TJ	37	36	34	34
Natural gas	TJ	48'390	41'070	47'230	51'290
NG heat only boilers	TJ	47'870	40'571	46'722	50'782
NG turbines	TJ	0	0	0	0
NG engines	TJ	520	499	508	508
Other bituminous coal	TJ	400	400	400	400
Lignite	TJ	0	0	0	0
Biomass	TJ	20'276	16'782	18'476	20'236
Gasoline (gardening)	TJ	154	151	148	145

Underlying data for the activity data on mobile non-road sources (1A4aii and 1A4bii) like vehicle stock and operating hours are shown in Annex A3.1.4.

For source category 1A4c, the following activity data is reported:

Activity data for grass drying (in tons of dried grass) is provided by the Swiss association of grass drying plants VSTB (EMIS 2015/1A4c). In this data set for the first time for this submission also the actual fuel consumption for grass drying is available and used from now onwards for emissions calculations.

Activity data for non-road machinery are shown in Annex A3.1.4 (INFRAS 2008, Prognos 2012a, Keller/INFRAS 2013).

Activity data regarding biomass use are based on Swiss wood energy statistics (SFOE 2014b) as explained in 3.2.4.1.

Table 3-53 documents the fuel use in source category 1A4c Agriculture/Forestry. Machinery is the largest source, with 86% fuel consumption of source category 1A4c compared to grass drying with 6% and biomass with 8%. Fuel consumption in machinery increased by 7.8% since 1990 while consumption from grass drying decreased significantly by 75.8%.

Table 3-53 Activity data in 1A4c Agriculture/Forestry/Fishing.

Source/Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1A4c Agriculture/forestry/fishing	TJ	8'598	8'624	8'569	8'547	8'490	8'495	8'519	8'424	8'415	8'392
Drying of grass (gas oil, natural gas, biomass)	TJ	1'895	1'828	1'748	1'683	1'620	1'544	1'482	1'409	1'349	1'291
Machinery (diesel oil, gasoline)	TJ	6'275	6'308	6'342	6'375	6'409	6'443	6'471	6'500	6'529	6'558
Biomass	TJ	428	488	480	489	462	509	565	515	537	543

Source/Fuel	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1A4c Agriculture/forestry/fishing	TJ	8'317	8'211	8'173	8'210	8'212	8'240	8'098	8'232	8'236	8'343
Drying of grass (gas oil, natural gas, biomass)	TJ	1'223	1'077	1'061	1'055	1'039	994	845	948	822	856
Machinery (diesel oil, gasoline)	TJ	6'587	6'588	6'589	6'590	6'591	6'592	6'658	6'724	6'791	6'857
Biomass	TJ	507	546	523	565	582	653	595	559	623	630

Source/Fuel	Unit	2010	2011	2012	2013
1A4c Agriculture/forestry/fishing	TJ	8'361	8'333	8'219	7'872
Drying of grass (gas oil, natural gas, biomass)	TJ	739	891	685	458
Machinery (diesel oil, gasoline)	TJ	6'923	6'871	6'818	6'765
Biomass	TJ	698	572	716	650

3.2.8.3 Uncertainties and Time-Series Consistency

The uncertainty of CO_2 emissions from fuel combustions is described in the uncertainty analysis in chapter 3.2.4.4 . Uncertainty in emissions of other non-CO_2 gases is estimated to be medium: 30% for CH_4 and 80% for N_2O (see Table 1-11).

Consistency: Time series for 1A4 Other sectors are all considered consistent.

3.2.8.4 Category-specific QA/QC and Verification

The general QA/QC procedures are described in section 1.2.3. Furthermore QA/QC procedures conducted for all 1A source categories are listed in 3.2.4.5

3.2.8.5 Category-Specific Recalculations

- 1A4: the AD (gas oil, natural gas) of 1A4ci Grass drying have been revised for 2012 based on updated data for 2013.
- 1A4: in the past consumption of biogas did not include statistical difference to the Swiss overall energy statistic. This difference is now included in the activity data for boilers in 1A4c.

3.2.8.6 Category-Specific Planned Improvements

For submission 2016 the consideration of the revised non-road model in data reporting is envisaged.

3.2.9 Source Category 1A5 - Other

3.2.9.1 Source Category Description

Approach 1 Key categories 1A5
CO_2 from the combustion of Liquid Fuels (trend)

All of the Swiss source categories refer to mobile sources of military activities (1A5b). Stationary activities are not occurring.

Table 3-54 Specification of Swiss source category 1A5 Other.

1A5	Source	Specification	Data Source
1A5a	Stationary	Not occurring in Switzerland (NO)	-
1A5b	Mobile: 1A5bi: Military aviation 1A5bii: Military non-road machines	1A5bi comprises emissions from military aviation. 1A5bii comprises non-road military machines, such as tanks and similar non-road vehicles.	Military aviation: Method, AD, EF: DDCS 2014 Military non-road machines: Method, AD, EF: INFRAS 2008, AD: Prognos 2012, Keller/INFRAS 2013

3.2.9.2 Methodological Issues

Military non-road vehicles

The emissions of military non-road machinery (excluding aviation) are modelled by the same approach as all other mobile non-road sources using the non-road model developed by INFRAS (2008). For details refer to Chapter 3.2.4.1.2 and 3.2.7.2.

Military aviation

To calculate the emissions from military aviation, a Tier 1 method is used. The fuel consumption 1990–2013 is known on an annual basis (DDPS 2014). A very small fraction of fuel is consumed for training abroad and might be allocated under “International aviation” (less than 3% of total military aviation consumption). Since the exact numbers for the fuels used abroad is not known, it is not subtracted from the total consumption but included under national military aviation, as recommended by the IPCC Guidelines (2006, chapter 3.6.1.4). Emissions of NO_x, CO and VOC have been modelled in detail by the Federal Office for Military Aviation (Bundesamt für Betriebe der Luftwaffe) for 1990 and 1995. From these inputs, FOEN determined average emission factors 1990 and 1995. For 1991-1994 the emission factors are linearly interpolated. For 1996-2013, the factors for 1995 are used. The emissions are then calculated yearly by multiplying the average emission factors with the activity data.

The extension of the emission modelling to CO_2, CH_4, N_2O, NMVOC and SO_2 is also accomplished by FOEN.

Emission factors for military non-road vehicles

- The emission factors for CO_2 are country-specific and are linearly interpolated between 1998-2013 and assumed to be constant in the years before with values 73.3 t/TJ for diesel oil, 73.8 t/TJ for gasoline and 56.4 t/TJ for CNG (equal to natural gas) for the year 2013, see Table 3-11.
- For SO_2 the emission factors are country-specific and are given in Table A – 29 in Annex 3.1.5.
- The emission factors for all other gases are country-specific and shown in Table A – 18 to TAbel A – 25 in the Annex A3.1.4 (INFRAS 2008). The NMVOC emissions are calculated as the difference of VOC and CH_4 emissions.

Note that emission factors in the unit of kg/h may be downloaded by query from the public part of the non-road database INFRAS (2008).

Emission factors for military aviation

- CO_2: The emission factor is country-specific and is based on analyses of fuel samples (see Table 3-11). The value for 2013 is 72.8 t/TJ.
- NO_x, VOC, CO: Engine producer information is used (CORINAIR, for details see SAEFL 1996: p. 202) for calculation of the emission factors in 1990 and 1995. For 1991-1994 the values are linearly interpolated between 1990 and 1995. For 1996-2013, the values 1995 are used.
- CH_4, NMVOC: For VOC, aircraft-specific information used for calculation of the emission factors in 1990 and 1995. For 1991-1994 the values are linearly interpolated between 1990 and 1995. For 1996-2013, the values 1995 are used. The division of VOC into CH_4 and NMVOC is carried out by a constant split of 53%: 47% (country-specific).
- N_2O: The implemented emission factor for N_2O is 2.356 kg/TJ.

- SO_2: The emission factor is taken from the 2006 IPCC Guidelines, 22 kg/TJ, and is assumed to be constant over the period 1990–2013 (IPCC 2006)
-

Activity data for military non-road vehicles and military aviation

Fuel consumption data is shown in Table 3-55. The underlying data for military non-road such as vehicle stock and operating hours are shown in Table A - 27 and Table A - 28 in Annex A3.1.4.

Fuel consumption of military aviation is copied from the logbooks of the military aircrafts and summed up yearly (DDPS 2014).

Table 3-55 Activity data (fuel consumption) for military non-road vehicles and military aviation

1A5 Other	Fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
		fuel consumption in TJ									
Military non-road	Diesel oil	48	48	48	48	49	49	49	49	50	50
Military non-road	Gasoline	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Military aviation	Jet kerosene	2'732.7	2'495.4	2'382.2	2'268.3	2'192.2	1'954.5	1'806.5	1'940.6	1'926.7	1'734.7

1A5 Other	Fuel	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
		fuel consumption in TJ									
Military non-road	Diesel oil	50	50	49	49	48	48	48	48	48	48
Military non-road	Gasoline	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Military aviation	Jet kerosene	1'794	1'757	1'840	1'644	1'491	1'624	1'676	1'577	1'505	1'529

1A5 Other	Fuel	2010	2011	2012	2013
		fuel consumption in TJ			
Military non-road	Diesel oil	48	48	47	46
Military non-road	Gasoline	0.6	0.6	0.6	0.6
Military aviation	Jet kerosene	1'592	1'420	1'527	1'542

3.2.9.3 Uncertainties and Time-Series Consistency

For a general description of the uncertainty analysis and time series consistency of the Energy Sector see Chapter 3.2.4.4. There are no source specific uncertainties.

Consistency: Time series for 1A5 Other are all considered consistent.

3.2.9.4 Category-specific QA/QC and Verification

The general QA/QC measures are described in section 1.2.3 and partly also in chapter 3.2.4.5.

The activity data of military aviation (kerosene consumption) (1A5b) is provided by the Federal Department of Defence, Civil Protection and Sport. For a compatibility check with the emission data base of civil aviation, they are sent to the FOCA (office of the Federal Department of the Environment, Transport, Energy and Communications).

A further compatibility check is carried out by the NIR authors of the energy chapter. No peculiarities have been detected by the specialists in the time series of the kerosene consumption of military aviation.

3.2.9.5 Category-Specific Recalculations

- 1A5b: New calorific values for gasoline, diesel, gas oil and kerosene based on new measurements for the year 2013. Therefore new CO_2 emission factor time series were generated. Now the emission factors are constant from 1990-1998 with the old measures and interpolated between 1998-2013 to the new measurements for 2013.

3.2.9.6 Category-specific Planned Improvements

For submission 2016 the consideration of the revised non-road model is envisaged.

3.3 Source Category 1B – Fugitive Emissions from Fuels

This source category is split into two sub-categories: Fugitive emissions from solid fuels (1B1, not occurring in Switzerland) and fugitive emissions from oil and natural gas (1B2). The term fugitive emissions is broadly applied and comprises all greenhouse gas emissions from oil and gas systems except contributions from fuel combustion. Oil and natural gas systems comprise all infrastructure required to produce, collect, process or refine and deliver natural gas and petroleum products to market. Fugitive emissions from oil and natural gas systems are accounted for in subcategory 1B2 of the energy sector.

The only relevant source categories of fugitive emissions in Switzerland are:

- Oil (1B2a)
- Natural gas (1B2b)
- Venting and flaring (1B2c)

Approach 1 Key categories 1B2

CH_4 from fugitive emissions of Oil and Natural Gas (level and trend)

Approach 2 Key categories 1B2

CH_4 from fugitive emissions of Oil and Natural Gas (trend)

3.3.1 Source Category 1B1 - Solid Fuels

Coal mining is not occurring in Switzerland.

3.3.2 Source Category 1B2a - Oil

3.3.2.1 Source Category Description

In Switzerland, oil production is not occurring. Fugitive emissions in the oil industry result exclusively from the two refining companies and several fuel handling stations. Production from the refining companies covers around 40% of the oil consumption in Switzerland. The other 60% are imports of final products. The two oil pipelines are very short in Switzerland (approximately 40 km and 70 km respectively) and are mainly laid underground.

The following source categories occur in Switzerland:

- Transport (1B2a iii)
- Refining / Storage (1B2a iv)
- Distribution of Oil Products (1B2a v)

Table 3-56 Specification of source category 1B2a Fugitive Emissions from Oil.
EMIS 2015/… refers to the internal documentation of the emission database and contains further references regarding specific AD and/or EF.

1B2	Source	Specification	Data Source
1B2a	Oil	Emissions from refining/storage of oil and the distribution of oil products: transport of crude oil in pipelines	AD: EV 2014, SFOE 2014 EF: IPCC 2006, EMIS 2015/1B2a

3.3.2.2 Methodological Issues

For source 1B2a Oil, emissions of CH_4 are reported, which occur only in 1B2a iii and 1B2a iv. Indirect emissions resulting from this source category are reported in chapter 9.

Emissions are calculated based on a Tier 1 approach. Fugitive emissions from fuels are calculated by multiplying level of activity by emission factor.

Emission factors

For oil transport (1B2a iii), the default emission factors from the 2006 IPCC guidelines for pipeline transportation are used to calculate emissions. Values provided in Table 3-57 are converted using a crude oil density of 0.82 t/m^3.

For oil refining and storage (1B2a iv), country-specific emission factors for CH_4 and NMVOC are used. The emission factors for CH_4 are delineated from an emission estimation project in one of the refineries in 1992 named CRISTAL. The estimation from the other refinery is assumed to be twice as high, because the technology of the plant is older. Then an arithmetic average has been calculated depending on the quantity of crude oil used in both refineries (EMIS 2015/1A2b a iv).

For oil distribution from storage tanks and gasoline stations (1B2a v), CO_2 emission factors are based on the conversion factor used in the NIR of the Netherlands. The NMVOC emission factor for oil distribution from tanks and gasoline stations is country-specific, based on a model which takes annual gasoline sales and technical equipment of gasoline stations and storage tanks into account (see documentation in EMIS 2015/1B2a v Benzinumschlag Tanklager and EMIS 2015/1B2a v Benzinumschlag Tankstellen). An expert team (Weyer and Partner AG) is in charge of providing annual updates of the modelled NMVOC emissions based on their own database of Swiss storage tanks and gasoline vapour recovery systems. The model is calibrated with spot checks of the gas recovery systems of gas stations.

Table 3-57 Emission Factors for 1B2a Oil.

Source/fuel	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
	g/t	g/t	kg/TJ	kg/TJ	kg/TJ	g/t	kg/TJ
1B2a Oil products							
Oil transport	0.60	6.59	NA	NA	NA	65.9	NA
Oil refining and storage	1356	45	NA	NA	NA	430	NA
Gasoline storage tank	888	NA	NA	NA	NA	282	NA
Gasoline station	1296	NA	NA	NA	NA	411	NA

Activity Data

For oil transport (1B2a iii) and oil refining and storage (1B2a iv), activity data (crude oil use in the two refineries) are based on annual statistics of the Swiss Petroleum Association (EV 2014).

For oil distribution from storage tanks and gasoline stations (1B2a v), gasoline sales based on the Swiss overall energy statistics (SFOE 2014), corrected for consumption of Liechtenstein, are used as activity data.

Since 1990, import of crude oil increased by 57% and gasoline sales decreased by 24%.

Table 3-58 Activity data for 1B2a Oil

1B2a Oil products	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Crude oil	t	3'127'000	4'671'000	4'317'000	4'764'000	4'880'000	4'657'000	5'290'000	4'984'000	5'070'000	5'093'000
Gasoline sales	t	3'682'727	3'834'439	3'972'485	3'682'707	3'682'344	3'568'755	3'660'597	3'800'552	3'829'912	3'957'500

1B2a Oil Products	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Crude oil	t	4'649'000	4'927'000	4'924'000	4'642'000	5'219'000	4'877'000	5'563'000	4'720'000	5'133'000	4'833'000
Gasoline sales	t	3'959'777	3'851'123	3'775'729	3'758'255	3'691'452	3'579'577	3'470'666	3'437'074	3'362'390	3'272'200

1B2a Oil Products	Unit	2010	2011	2012	2013
Crude oil	t	4'546'000	4'452'000	3'455'000	4'935'000
Gasoline sales	t	3'157'100	3'036'076	2'928'858	2'795'522

3.3.2.3 Uncertainties and Time-Series Consistency

Based on expert judgement, a preliminary uncertainty assessment of all sources in source category 1B2 results in medium confidence in the emissions estimate (see Table 1-11).

Consistency: Time series for 1B2a Oil are all considered consistent.

3.3.2.4 Category-Specific QA/QC and Verification

The general QA/QC measures are described in section 1.2.3 and partly also in 3.2.4.5. No further source specific activities undertaken for Fugitive emissions Oil (1B2a).

3.3.2.5 Category-Specific Recalculations

No recalculations were carried out for this submission.

3.3.2.6 Category-Specific Planned Improvements

No source-specific planned improvements are envisaged.

3.3.3 Source Category 1B2b - Natural Gas

3.3.3.1 Source Category Description

Emissions from natural gas production (1B2b ii) are only occurring for the years of operation of the single production plant in Switzerland from 1985 - 1994. Other emissions in this sector occur from natural gas transmission (1B2b iv) and distribution (1B2b v). Emission from transmission include leakages from gas pipelines, small-scale damages, revision processes of the pipeline network and leakage of network components. Major accidents and isolated events are reported under other (1B2b vi).

The following source categories occur in Switzerland:

- Production (1B2b ii) (only 1990-1994)
- Transmission and storage (1B2b iv)
- Distribution (1B2b v)
- Other (1B2b vi) (isolated events in single years)

Table 3-59 Specification of source category 1B2b Fugitive emissions from natural gas.
EMIS 2015/… refers to the internal documentation of the emission database and contains further references regarding specific AD and/or EF.

1B2	Source	Specification	Data Source
1B2b	Natural Gas	Emissions from transmission and distribution of gas	AD: SFOE 2014, Quantis 2014 EF: IPCC 2006, Quantis 2014

3.3.3.2 Methodological Issues

For source category 1B2b ii, emissions are calculated based on annual production data and default emission factors (IPCC Tier 1 approach). Emissions from gas transmission and distribution are calculated with a country-specific method, based on length, type and pressure of the gas pipelines, supplemented by estimates of fugitive emissions from distribution network components (regulators, shut off fittings and gas meters). Source category 1B2b vi is based on accident and emission reports from the gas pipeline operators. Losses from end-users (household or industry) are reported in the corresponding source category in sector 1A.

Emission factors

CO_2, CH_4 and NMVOC default emission factors for natural gas production are taken from the 2006 IPCC Guidelines as documented in EMIS 2015/1B2b Gasproduktion.

Emission factors for gas transport and distribution losses (source 1B2b iv and 1B2b v) have been reassessed in a recent study (Quantis 2014, e.g. table 6 for emission factors of pipelines, table 10 for emissions factors of minor incidents, table 11 for emission factors for network maintenance). Emission factors are taken from the literature and base mostly on the study of Battelle (1994) and Xinmin (2004). Due to insufficient data regarding distribution network components (regulators, shut-off fittings and gas meters) and appropriate emission factors, emissions are estimated as a fixed percentage of the network losses.

Activity Data

Activity data for fugitive emissions from gas production (1B2b ii) are the actual gas production data (SFOE 2014). For source categories 1B2b iv and 1B2b v, information regarding the gas transport and distribution network from the Swiss Gas and Water Industry Association (SGWA) is used as activity data (see Quantis 2014, table 9). Since 1990, the natural gas net increased by 73% from 142'000 km in 1990 to 246'000 km in 2012. In the same period, the natural gas consumption increased by 62% from 21'000 to 34'000 GWh.

Fugitive emissions from pipelines are the major emission source in source category 1B2b. Fugitive emissions from damages and ruptures of the pipelines, maintenance of the pipelines and the components are very small (Quantis 2014). Total CH_4 emissions from gas transmission and distribution decreased by 36% due to gradual replacement cast-iron pipes with polyethylene pipes.

Concerning isolated events in source category Other (1B2b vi), there were two accidents reported by the transit pipeline operator, one in 2010 and 2011. These events have also been taken into account in recent reassessment of fugitive emissions from the gas industry (Quantis 2014).

3.3.3.3 Uncertainties and Time-Series Consistency

According to the assessment by Quantis (2014), an uncertainty of 30% is estimated for fugitive CH_4 emissions from natural gas pipelines in Switzerland.

A preliminary uncertainty assessment of all other sources in source category 1B2 based on expert judgement results in medium confidence in the emissions estimate (see Table 1-11).

Consistency: Time series for 1B2b Natural gas are all considered consistent.

3.3.3.4 Source-Specific QA/QC and Verification

The general QA/QC measures are described in section 1.2.3.

As suggested by the 2006 IPCC guidelines the gas industry was involved in the reassessment of fugitive emissions from the natural gas system (Quantis 2014).

3.3.3.5 Category-Specific Recalculations

No recalculations were carried for this submission.

3.3.3.6 Category-Specific Planned Improvements

No source-specific planned improvements are envisaged.

3.3.4 Source Category 1B2c – Venting and flaring

3.3.4.1 Source Category Description

In general flaring means burning of waste natural gas and hydrocarbon liquids by flares or incinerators as a disposal option rather than for the production of useful heat or energy. Flaring is most common at production, processing, upgrading and refining facilities. In Switzerland, oil and natural gas production is not occurring. Emissions from flaring result from the torches which are operational at the two refineries (1B2c i Flaring).

Table 3-60 Specification of source category 1B2c Venting and flaring.
EMIS 2015/… refers to the internal documentation of the emission database and contains further references regarding specific AD and/or EF.

1B2	Source	Specification	Data Source
1B2 c	Venting / Flaring	The combustion of excess gas at the oil refinery	AD: EV 2014 EF: EMIS 2015/1B2c

3.3.4.2 Methodological Issues

For source category 1B2c Venting/Flaring (Oil), CO_2 as well as CH_4, N_2O, NO_x, CO and NMVOC are considered.

Emission factors

Emission factors are based on data from the refining industry and expert estimates as documented in EMIS 2015/1B2c Raffinerie Abfackelung.

Table 3-61 Emission factors for 1B2c Venting/Flaring.

Source/fuel	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
	g/t	g/t	g/t	g/t	g/t	g/t	g/t
1B2c Venting and flaring	8300	3.5	0.64	43	10	3.5	62

Activity data

For source category 1B2c, crude oil used is based on annual statistics of the Swiss Petroleum Association (EV 2014). This is the same activity data as for 1B2a Oil.

Table 3-62 Activity data for 1B2c Venting/Flaring.

1B2c Venting and flaring	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Crude oil used	t	3'127'000	4'671'000	4'317'000	4'764'000	4'880'000	4'657'000	5'290'000	4'984'000	5'070'000	5'093'000

1B2c Venting and flaring	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Crude oil used	t	4'649'000	4'927'000	4'924'000	4'642'000	5'219'000	4'877'000	5'563'000	4'720'000	5'133'000	4'833'000

1B2c Venting and flaring	Unit	2010	2011	2012	2013
Crude oil used	t	4'546'000	4'452'000	3'455'000	4'935'000

3.3.4.3 Uncertainties and Time-Series Consistency

A preliminary uncertainty assessment of all sources in source category 1B2 based on expert judgement results in medium confidence in the emissions estimate (see Table 1-11).

Consistency: Time series for 1B2c Venting and flaring are all considered consistent.

3.3.4.4 Category-Specific QA/QC and Verification

The general QA/QC measures are described in section 1.2.3. No category-specific QA/QC activities were undertaken.

3.3.4.5 Category-Specific Recalculations

No recalculations were carried out for this submission.

3.3.4.6 Category-Specific Planned Improvements

No source-specific improvements are planned.

3.4 Source Category 1C – CO_2 Transport and Storage

CO_2 transport and CO_2 storage is not occurring in Switzerland.

4 Industrial Processes and Product Use

4.1 Overview

This chapter provides information on the estimation of the greenhouse gas emissions from sector 2 Industrial processes and product use. The following source categories are reported:

- 2A Mineral industry
- 2B Chemical industry
- 2C Metal industry
- 2D Non-energy products from fuels and solvent use
- 2E Electronics industry
- 2F Product uses as substitutes for ozone depleting substances (ODS)
- 2G Other product manufacture and use
- 2H Other

Emissions within this sector comprise greenhouse gas emissions as by-products from industrial processes and also emissions of F-gases during production, use and disposal. Emissions from fuel combustion in industry are reported in source category 1A2 under sector 1 Energy.

According to the 2006 IPCC guidelines this sector provides newly information on the greenhouse gas emissions from solvent and product use. CO_2 emissions from solvent and partly from product use are due to post-combustion of NMVOC in order to reduce NMVOC in exhaust gases. The disposal of solvents is reported in the waste sector (chapter 7).

Please note that for several industrial processes within source categories 2A Mineral industry, 2B Chemical industry and 2C Metal industry data and information of emission factors and activity data are classified as confidential (C). For reviewers there is an additional version of chapter 4 Industrial processes and product use available, including all confidential data and information.

Figure 4-1 shows the development of greenhouse gas emissions in sector 2 between 1990 and 2013.

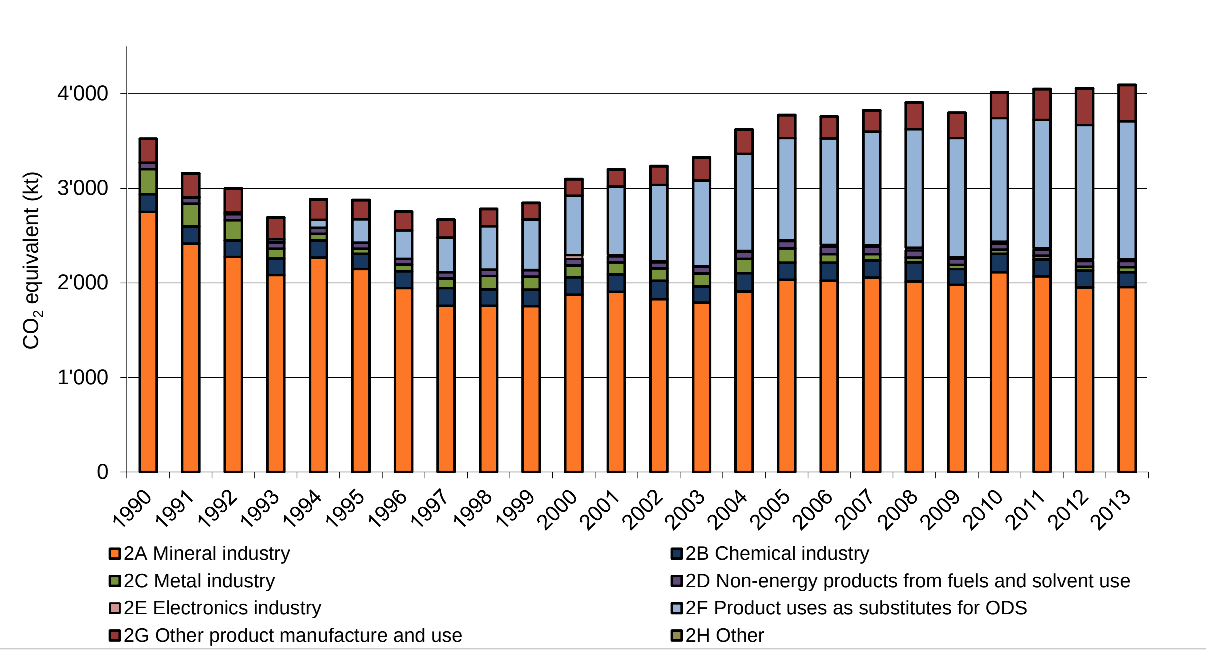


Figure 4-1 Switzerland's greenhouse gas emissions of sector 2 Industrial processes and product use 1990-2013.

2A Mineral industry remain the dominant source of sector 2 with a share of 47.8% of the greenhouse gas emissions in 2013 although they have decreased by 29% since 1990. 2B Chemical industry accounts for 3.8% and has decreased by 17% since 1990. 2C Metal industry and 2D Non-energy products contribute with 1.3% and 1.6%, respectively, in 2013, and have decreased by 80% and 3%, respectively.

2F Product uses as substitutes for ODS is of increasing importance: The emissions have inreased from 0.9 Gg CO_2 equivalents in 1990 to 1462 Gg CO_2 equivalents in 2013 and are currently responsible for 35.7% of total greenhouse gas emissions in sector 2. This is primarily due to the replacement of CFCs by HFCs in many technical applications. 2G Other product manufacture and use accounts for 9.4% of the total greenhouse gas emissions in 2013 and has increased by 54% since 1990. 2E Electronic industry and 2H Other are of little importance with regard to the overall greenhouse gas emissions of sector 2. They are responsible for 0.4% and less than 0.1%, respectively.

In Table 4-1 the development of greenhouse gas emissions in sector 2 Industrial processes and product use are given by gases. Dominant gases are CO_2 and F-gases with shares of 53.6% and 44.6%, respectively, of the emissions in 2013 whereas N_2O and CH_4 contribute with 1.7% and less than 0.1%, respectively. The relative trend of these gases referring to the base year 1990 is shown in Figure 4-2 and Figure 4-3.

Table 4-1 Greenhouse gas emissions of sector 2 Industrial processes and product use by gases in kt CO_2 equivalent for the period 1990-2013.

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	CO_2 equivalent (kt)									
CO_2	3'095	2'754	2'608	2'358	2'524	2'375	2'206	2'036	2'028	2'034
CH_4	1.8	1.8	1.8	1.8	1.8	1.8	1.8	2.1	1.8	1.5
N_2O	171	162	150	142	146	140	133	121	119	115
F-gases	254	239	238	188	209	357	408	507	633	695
Sum	3'522	3'157	2'997	2'691	2'881	2'873	2'749	2'666	2'782	2'845

Gas	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	CO_2 equivalent (kt)									
CO_2	2'163	2'188	2'127	2'094	2'238	2'354	2'295	2'304	2'267	2'195
CH_4	1.7	1.9	1.8	1.7	2.5	2.6	2.3	2.6	2.9	1.9
N_2O	115	113	113	107	109	100	104	101	109	99
F-gases	819	895	993	1'124	1'271	1'318	1'355	1'415	1'526	1'501
Sum	3'098	3'198	3'235	3'327	3'621	3'775	3'757	3'823	3'904	3'796

Gas	2010	2011	2012	2013
	CO_2 equivalent (kt)			
CO_2	2'356	2'305	2'183	2'195
CH_4	2.7	2.8	2.8	2.1
N_2O	102	94	94	71
F-gases	1'556	1'649	1'775	1'824
Sum	4'017	4'051	4'056	4'093

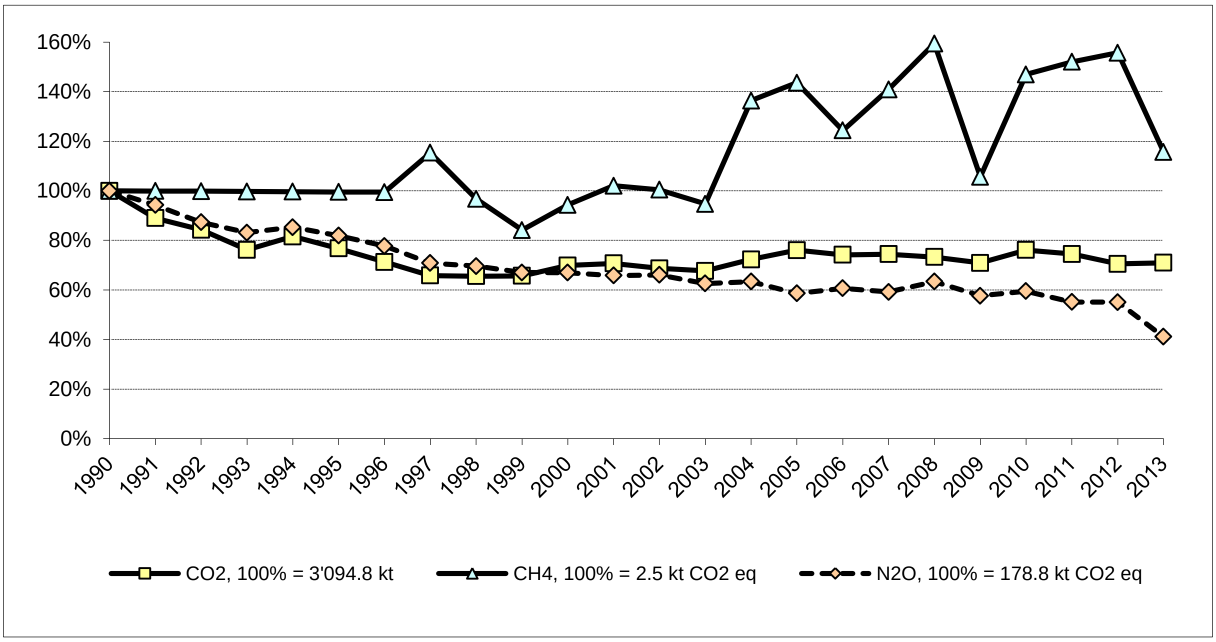


Figure 4-2 Relative trends of the greenhouse gases of sector 2 Industrial processes and product use in the period 1990-2013. The base year 1990 represents 100%.

Figure 4-2 shows that in the period 1990-2013 the emissions of CO_2 and N_2O from sector 2 Industrial processes and product use have decreased by 29% and 59%, respectively, compared to the base year 1990. Emissions of CH_4 have increased by 16% in the same time span though the development has been fluctuating in this period.

Figure 4-3 shows that the emissions of F-gases have increased sevenfoldly compared to the year 1990. Main contributions in the inventory 1990 result from the PFC emissions in the smeltering process of aluminium production (chapter 4.4.2.2) and from the use of SF_6 in electrical equipment and sound proof windows (chapter 4.8.2.1 and chapter 4.8.2.2). The increase afterwards is due to the increasing product uses as substitutes for ODS (chapter 4.7), most relevant and main source of F-gases emissions in 2013 is the use of HFC in refrigeration and air conditioning.

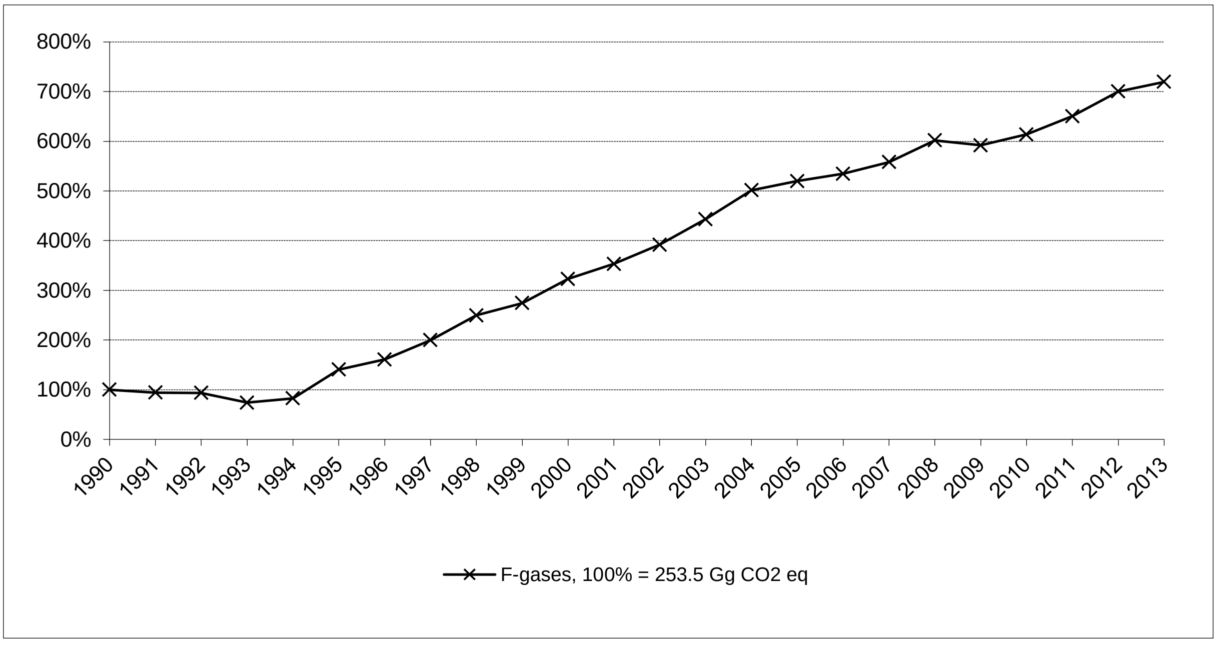


Figure 4-3 Relative trends of the F-gases of sector 2 Industrial processes and product use in the period 1990-2013. The base year 1990 represents 100%.

4.2 Source Category 2A – Mineral Industry

4.2.1 Source Category Description

Approach 1 Key category 2A1

CO_2 emissions from Cement production (level and trend).

Approach 1 Key category 2A4

CO_2 emissions from Other process uses of carbonates (trend).

Approach 2 Key category 2A4

CO_2 emissions from Other process uses of carbonates (trend).

Source category 2A Mineral industry comprises process emissions from production of cement, lime, glass, fine ceramics, brick and tile, rock wool as well as the use of sodium bicarbonate.

Table 4-2 Specification of source category 2A Mineral industry. EMIS 2015/… refers to the internal documentation of the emission database and contains further references regarding specific AD and/or EF.

2A	Source	Specification	Data Source
2A1	Cement production	Geogenic CO_2 emissions from calcination process in cement production; Emissions of CO_2, NOx, CO, NMVOC and SO_2 from blasting operations	AD, EF: EMIS 2015/2A1 Zementwerke Rohmaterial AD, EF: EMIS 2015/2A1 Zementwerke übriger Betrieb
2A2	Lime production	Geogenic CO_2 emissions from calcination process in lime production; Emissions of CO_2, NOx, CO, NMVOC and SO_2 from blasting operations	AD, EF: EMIS 2015/2A2 Kalkproduktion, Rohmaterial AD, EF: EMIS 2015/2A2 Kalkproduktion, übriger Betrieb
2A3	Glass production	Geogenic CO_2 emissions from production of container and tableware glass, and glass wool	AD: EMIS 2015/2A3 Hohlglas Produktion, EMIS 2015/2A3 Glas übrige Produktion, EMIS 2015/2A3 Glaswolle Produktion Rohprodukt EF: IPCC 2006, EMIS 2015/2A3 Hohlglas
2A4	Other process uses of carbonates	Geogenic CO_2 emissions from fine ceramics, brick and tile and rock wool production as well as from use of sodium bicarbonate; Emissions of CO_2, NOx, CO, NMVOC and SO_2 from blasting operations in plaster production	EF: IPCC 2006, EMIS 2015/2A4a Ziegeleien AD: EMIS 2015/2A4a Feinkeramik Produktion, EMIS 2015/2A4d Steinwolle Produktion, EMIS 2015/2A4a Ziegeleien AD, EF: EMIS 2015/2A4d Gips-Produktion übriger Betrieb, EMIS 2015/2A4d Karbonatanwendung weitere

4.2.2 Methodological Issues

4.2.2.1 Cement production (2A1)

Emissions of geogenic CO_2 occur during the production of clinker which is an intermediate component in the cement manufacturing process. During the production of clinker, limestone, which is mainly calcium carbonate ($CaCO_3$) is heated (calcined) to produce lime (CaO) and CO_2 as by-product. The CaO reacts subsequently with minerals in the raw materials and yields clinker. During this reaction step no further CO_2 is emitted. Clinker is then mixed with other components such as gypsum to make cement.

In Switzerland there are six plants producing clinker and cement. The Swiss plants are rather small and do not exceed a capacity of 3’000 tonnes of clinker per day. All of them use modern dry process technology.

Blasting operations in the limestone quarries are another source of emissions for both CO_2 and precursor greenhouse gases such as NO_x, CO, NMVOC and SO_2.

Methodology

Calcination process:

The geogenic CO_2 emissions from the calcination process in cement production are determined by a Tier 2 method according to 2000 IPCC good practice guidance (IPCC 2000, chapter 3.1.1 Cement production). For cement production in Switzerland this results in the following formula:

CO_2 Emissions = $M_{Clinker} \bullet EF_{Clinker} \bullet CKD_{Correction\ factor}$

In Switzerland no long wet or long dry kilns but only modern preheater or precalciner kilns are used and also no so-called low-alkali cement is produced. Therefore there is no land-filling of calcined cement dust (CKD) in Switzerland. In the cement plants all the filter dust is collected in high performance electrostatic precipitator or bag filters (having an efficiency of more than 99.999%) and being recycled to the kiln feed. In some cases small portions of the CKD are added directly to the cement as filler. Due to the kiln technology used in Switzerland the decarbonating degree of the CKD is almost equal to that of the kiln feed, meaning, that this CKD has not been decarbonated yet. Therefore the CKD correction factor is 1.00.

Blasting operations:

The emissions resulting from blasting operations during the digging of limestone are included following a country specific method. Emissions related to blasting operations are calculated by multiplying the annual clinker output by emission factors. Please note that the CO_2 emissions from "blasting" are related only to the usage of explosive in the quarries and not to fuel consumption of e.g. bulldozers etc. The amount of used explosive is reported to be 0.13 kg/t cement[11] (EMIS 2015/2A1 Zementwerke übriger Betrieb).

Total emissions reported for the production of cement are the sum of emissions from calcination process and blasting operations. The share of CO_2 emissions from blasting operations in limestone quarries is well below one tenth of a per cent of the geogenic CO_2 emissions from the calcination process.

Emission Factors

Calcination process:

The emission factor for CO_2 for calcination is a country-specific value depending on the composition of the raw material. The emission factors for the entire time series are listed in Table 4-3. In 2013 it amounts to 530.56 kg CO_2 per ton of clinker produced. The IPCC

[11] The CO_2 emission factor for the use of blasting agents amounts to 600 kg CO_2/t of blasting agent. For the average amount on blasting agent used per kg cement measurement data for the year 2002 were taken. Measurement data were available for four Swiss cement plants, covering more than 60% of the Swiss cement production. Therefore this information is regarded as representative for the Swiss situation. The average blasting agent input per ton of cement amounts to 0.13 kg. The emission factor for CO_2 per ton of clinker amounts to 34.1 g/t (conversion factor cement to clinker is assumed to be 1.1).

approach neglects CO_2 emissions from decomposition of $MgCO_3$, which are taken into account in this country-specific value.

Table 4-3 CO_2 emission factor for calcination in 2A1 Cement Production 1990 to 2013 (EMIS 2015/2A1 Zementwerke Rohmaterial).

2A1 Cement production	Unit	1990 - 2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Calcination, CO_2	kg/t clinker	525.00	530.60	527.90	528.58	529.26	531.00	532.15	530.56	530.56	530.56

Blasting operations:

The emission factors are country-specific based on measurements and data from industry and expert estimates as documented in EMIS 2015/2A1 Zementwerke übriger Betrieb. They are given per ton of clinker.

Table 4-4 Emission factors for CO_2, NO_x, CO, NMVOC and SO_2 from blasting operations in g/t clinker from source category 2A1 Cement Production in 2013 (EMIS 2015/2A1 Zementwerke übriger Betrieb).

2A1 Cement production	Unit	CO_2	NO_X	CO	NMVOC	SO_2
Blasting operations	g/t clinker	34.10	3.30	3.30	8.58	0.14

Activity Data

Activity data on annual clinker production is provided by industry and documented in EMIS 2015/2A1 Zementwerke Rohmaterial and EMIS 2015/2A1 Zementwerke übriger Betrieb.

Table 4-5 Activity data of clinker production in Switzerland for the period 1990-2013 in Gg (EMIS 2015/2A1 Zementwerke Rohmaterial and EMIS 2015/2A1 Zementwerke übriger Betrieb).

2A1 Cement production	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Clinker production	Gg	4'808	4'189	3'927	3'564	3'930	3'706	3'337	2'994	2'995	2'992

2A1 Cement production	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Clinker production	Gg	3'214	3'275	3'150	3'081	3'265	3'442	3'452	3'512	3'461	3'443

2A1 Cement production	Unit	2010	2011	2012	2013
Clinker production	Gg	3'642	3'587	3'368	3'415

4.2.2.2 Lime production (2A2)

During the production of lime calcium carbonate ($CaCO_3$) is heated (calcined) yielding burnt lime (CaO) and CO_2 as by-product. In Switzerland there is only one plant producing lime. There is no industry in Switzerland producing lime for its own requirements except for sugar production. A request to the sugar producing plants Aarberg and Frauenfeld confirmed that indeed they produce lime from limestone in own shaft kilns but that the CO_2 is re-captured in the sugar production process. Thus no CO_2 emissions occur.

Blasting operations in quarry is another source of emissions for both CO_2 and precursor emissions such as NO_x, CO, NMVOC and SO_2.

Methodology

Calcination process:

The geogenic CO_2 emissions from the calcination process in lime production are determined by a country-specific approach according to 2000 IPCC good practice guidance (IPCC 2000, chapter 3.1.2 Lime production). For lime production in Switzerland this results in the following formula:

CO_2 Emissions = $M_{Lime} \bullet EF_{Lime}$

Blasting operations:

The emissions resulting from blasting operations during the digging of limestone are included following a country-specific method. They are calculated by multiplying the annual lime production by emission factors. Please note that the CO_2 emissions from "blasting" are related to the usage of explosive only and are not related to fuel consumption of e.g. bulldozers etc.

Total emissions reported for the production of lime are the sum of emissions from calcination process and blasting operations. The share of CO_2 emissions from blasting operations in the quarry is well below one tenth of a per cent of the geogenic CO_2 emissions from the calcinations process.

Emission Factors

Calcination process:

The emission factor for CO_2 from calcination of limestone depends both on the purity of the limestone and the grade of calcination (i.e. amount of rest CO_2 remaining in the final lime). The plant specific value has been calculated based on industry declaration and is assumed to be constant over time (EMIS 2015/2A2 Kalkproduktion, Rohmaterial). The value is considered confidential, however, is available to reviewers.

Blasting operations:

The emission factors are country-specific as documented in EMIS 2015/2A1 Kalkproduktion, übriger Betrieb. The values are considered confidential, however, is available to reviewers.

Table 4-6 CO_2 emission factor for calcination process in lime production in kg/t lime and emission factors for CO_2, NOx, CO, NMVOC and SO_2 from blasting operations in g/t lime in 2013 (EMIS 2015/2A2 Kalkproduktion, Rohmaterial and EMIS 2015/2A1 Kalkproduktion übriger Betrieb).

2A2 Lime production	**Unit**	**CO_2**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Calcination	kg/t	C	NA	NA	NA	NA
Blasting operations	g/t	C	C	C	C	C

Activity Data

Activity data on annual lime production are based on data from the one existing plant in Switzerland, documented in the EMIS database (EMIS 2015/2A2 Kalkproduktion, Rohmaterial and EMIS 2015/2A1 Kalkproduktion übriger Betrieb). Detailed activity data are not reported as it is considered confidential.

Table 4-7 In the confidential NIR the respective table with activity data on lime production are separately reported and available to reviewers.

4.2.2.3 Glass production (2A3)

Source category 2A3 Glass production comprises geogenic CO_2 emissions from the carbonate containing raw materials, i.e. soda ash, limestone and dolomite. In Switzerland the following three glass types are produced: container glass, tableware glass and glass wool. Today there is only one production plant for container glass and tableware glass, respectively, after the other one closed in 2002 and 2006, respectively. Glass wool is produced in two plants.

Methodology

For determination of geogenic CO_2 emissions from glass production a Tier 2 method according to IPCC 2006 (vol. 3, chapter 2.4 Glass production) is used. For glass production in Switzerland this results in the following formula:

$$CO_2 \text{ Emissions} = M_{\text{Glass type}} \bullet EF_{\text{Glass type}} \bullet (1 - \text{cullet ratio})$$

The cullet ratio describes the share of recycled glass material which is used in the production. The melting of cullet causes no geogenic CO_2 emissions.

From 2005 onwards the geogenic CO_2 emissions from 2A3 Container glass production is determined according to a Tier 3 method based on the amount of carbonate containing raw materials used, i.e. soda, dolomite and limestone and their effective carbonate content.

Emission Factors

The emission factors for glass production in Switzerland are taken from IPCC 2006 (vol.3, chapter 2.4 Glass production, Table 2.6). For the production of container glass (1990-2004), tableware glass and glass wool the values for glass type container, tableware and fibreglass are taken, respectively. As the emission factors are material properties they remain constant over the time.

From 2005 onwards since the effective amounts of carbonate containing raw materials are available for 2A3 Container glass production the CO_2 emission factors of soda ash, dolomite and limestone are taken from IPCC 2006 (vol. 3, chapter 2.5 Other process uses of carbonates, Table 2.1). As these emission factors are material properties they remain constant over time.

Table 4-8 Geogenic CO_2 emission factor for glass production in g/t glass and g/t carbonate containing raw material (IPCC 2006).

2A3 Glass production	Unit	CO_2 geogenic	
Glass wool (fibre glass insulation)	g/t	250'000	
Glass (speciality tableware)	g/t	100'000	
		1990–2004	**2005–2013**
Container glass	g/t	210'000	
Soda use	g/t soda		414'920
Dolomite use	g/t dolomite		477'320
Limestone use	g/t limestone		439'710

Activity Data and Cullet Ratios

Activity data are based on industry data from Swiss glass producers. For glass wool production activity data are based on data from the two glass wool production plants in Switzerland.

Source category 2A3 Glass production is dominated by the emission from the production of container glass. Today there is only one plant producing container glass (the second plant closed in 2002). The production activities have strongly decreased since 1990.

Detailed information on activity data for container glass production and tableware production is considered confidential as there is only one production plant for container glass and tableware glass, respectively. However, the detailed data are available to the reviewers.

Table 4-9 Glass production in Switzerland for the period 1990-2013 in Gg and cullet ratio in % as well as consumption of carbonate containing raw materials in container glass production from 2005 onwards in Gg (EMIS 2015/2A3 Hohlglas Produktion, EMIS 2015/2A3 Glas übrige Produktion and EMIS 2015/2A3 Glaswolle Produktion Rohprodukt).

2A3 Glass production	**Unit**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Container glass											
Production	Gg	C	C	C	C	C	C	C	C	C	C
Cullet ratio	%	C	C	C	C	C	C	C	C	C	C
Soda use	Gg	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dolomite use	Gg	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Limestone use	Gg	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Glass (speciality tableware)											
Production	Gg	C	C	C	C	C	C	C	C	C	C
Cullet ratio	%	C	C	C	C	C	C	C	C	C	C
Glass wool											
Production	Gg	24.3	22.8	23.4	21.7	24.9	24.2	19.9	25.6	27.5	32.1
Cullet ratio	%	21	26	49	53	65	45	61	66	65	67

2A3 Glass production	**Unit**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Container glass											
Production	Gg	C	C	C	C	C	C	C	C	C	C
Cullet ratio	%	C	C	C	C	C	NA	NA	NA	NA	NA
Soda use	Gg	NA	NA	NA	NA	NA	C	C	C	C	C
Dolomite use	Gg	NA	NA	NA	NA	NA	C	C	C	C	C
Limestone use	Gg	NA	NA	NA	NA	NA	C	C	C	C	C
Glass (speciality tableware)											
Production	Gg	C	C	C	C	C	C	C	C	C	C
Cullet ratio	%	C	C	C	C	C	C	C	C	C	C
Glass wool											
Production	Gg	31.1	25.2	19.9	25.9	32.7	37.5	38.1	44.5	44.4	33.5
Cullet ratio	%	69	65	59	62	65	65	73	71	69	69

2A3 Glass production	**Unit**	**2010**	**2011**	**2012**	**2013**
Container glass					
Production	Gg	C	C	C	C
Cullet ratio	%	NA	NA	NA	NA
Soda use	Gg	C	C	C	C
Dolomite use	Gg	C	C	C	C
Limestone use	Gg	C	C	C	C
Glass (speciality tableware)					
Production	Gg	C	C	C	C
Cullet ratio	%	C	C	C	C
Glass wool					
Production	Gg	35.7	41.4	38.7	33.4
Cullet ratio	%	71	72	61	67

4.2.2.4 Other process uses of carbonates (2A4)

Source category 2A4 Other process uses of carbonates comprises geogenic CO_2 emissions from the carbonate containing raw materials used in the production of ceramics (2A4a) and rock wool (2A4d) as well as from the use of sodium bicarbonate (2A4d). In addition also emissions from blasting operations in plaster production (2A4d) are reported.

Ceramics (2A4a)

Fine ceramics (2A4a)

In Switzerland the main production of fine ceramics is sanitary ware. The carbonate containing raw materials limestone and dolomite are used in product glazes only. The glazes contain small amounts of soda ash (Na_2CO_3) as well. All information on the fine ceramics production is documented in EMIS 2015/2A4a Feinkeramik Produktion.

Methodology

The geogenic CO_2 emissions from fine ceramics production are determined by a Tier 2 method according to 2006 IPCC guidelines (IPCC 2006, vol. 3, chapter 2.5 Other process uses of carbonates). For fine ceramics production in Switzerland this results in the following formula:

$$CO_2 \text{ Emissions} = (M_{Limestone} \bullet EF_{Limestone}) + (M_{Dolomite} \bullet EF_{Dolomite}) + (M_{Soda\ Ash} \bullet EF_{Soda\ Ash})$$

Emission Factors

The CO_2 emission factors of limestone, dolomite and soda ash are taken from IPCC 2006 (vol. 3, chapter 2.5 Other process uses of carbonates, Table 2.1). As these emission factors are material properties they remain constant over time.

Table 4-10 Geogenic CO_2 emission factors for 1990-2013 used for fine ceramics and the production of brick and tile in g/t carbonate containing raw material and g/t product, respectively (IPPC 2006, EMIS 2015/2A4a Ziegeleien).

2A4a Ceramics	Unit	CO_2 geogenic	
Fine ceramics			
Limestone use	g/t limestone	439'710	
Dolomite use	g/t dolomite	477'320	
Soda use	g/t soda	414'920	
		1990–2012	**2013**
Brick and tile production	g/t	117'000	100'000

Activity Data

Activity data for carbonate containing raw materials, i.e. limestone, dolomite and soda ash used in the glazes of the fine ceramics production are extrapolated values based on industry data from the largest production plant in Switzerland. Detailed activity data are considered confidential; however, it is available to the reviewers.

Brick and tile production (2A4a)

In Switzerland there are about 20 plants producing bricks and tiles. The manufacturing process uses limestone containing clay as main raw material.

Methodology

Concerning the release of geogenic CO_2 emissions from brick and tile production there has been no specific information on the employed raw materials available from Swiss industry for the past years up to 2011. In 2013, again, a request to the Swiss association of brick and tile industry (Verband Schweizerische Ziegelindustrie VSZ) was not successful.

The brickearth used in Switzerland for the production of bricks and tiles does not consist of pure and defined contents of clay minerals but its clay content is varying depending on the individual pit, comprising other minerals such as calcite, dolomite and quartz. Compared to other countries the fraction of carbonate containing raw material is relatively high. As described, data on the carbonate containing raw materials from the Swiss brick and tile industry were not received. Therefore, for the period 1990 until 2012 data from a comparison of geogenic CO_2 emissions based on representative analyses of the carbonate content of the clay used for brick and tile production in a number of plants in Switzerland and the European Union are applied. This study was carried out by the VSZ in 2012 (see EMIS 2015/2A4a Ziegeleien).

From 2013 onwards the brick and tile industry is legally obligated to report annually the geogenic CO_2 emissions from the carbonate containing raw materials (Federal Act on the Reduction of CO_2 Emissions, Swiss Confederation 2011 and Ordinance for the Reduction of CO_2 Emissions, Swiss Confederation 2012).

In order to estimate the geogenic CO_2 emissions from brick and tile production in Switzerland the following formula was used:

$$CO_2 \text{ Emissions} = M_{\text{brick and tile}} \bullet EF_{\text{brick and tile}}$$

Emission Factors

According to the above mentioned study, bricks emit a weighted average of 13.2% of geogenic CO_2 (variation range 5.4 - 24%) and roof tiles have a weighted average of 8.6% (variation range 5.6 - 13%). Based on the production shares of the largest Swiss brick producer a production ratio for bricks to tiles of 2:1 was assumed for the whole period from 1990 to 2012. This resulted in an average geogenic CO_2 emission factor of 117 kg CO_2/t brick and tile which was assumed for the time period 1990 to 2012.

Based on the plant specific monitoring data of the geogenic CO_2 emissions from the carbonate containing raw materials a production weighted emission factor of 100 kg CO_2/t brick and tile resulted for 2013. This procedure corresponds to a Tier 3 method according to IPCC 2006 guidelines. For emission factors see Table 4-10.

Activity Data

Activity Data are based on production data from the Swiss association of brick and tile industry and presented in following Table 4-11.

Table 4-11 Activity data for the production of fine ceramics including the use of limestone, soda and dolomite in the glazes, brick and tile, rock wool and plaster as well as other use of carbonates (sodium bicarbonate) in Switzerland for the period 1990-2013 in Gg (EMIS 2015/2A4).

2A4a Ceramics	**Unit**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Fine ceramics production	Gg	C	C	C	C	C	C	C	C	C	C
Limestone use	Gg	C	C	C	C	C	C	C	C	C	C
Dolomite use	Gg	C	C	C	C	C	C	C	C	C	C
Soda use	Gg	C	C	C	C	C	C	C	C	C	C
Brick and tile production	Gg	1'271	1'240	1'208	1'177	1'146	1'115	1'084	1'052	1'021	990
2A4d Other											
Rock wool production	Gg	C	C	C	C	C	C	C	C	C	C
Other use of carbonates	Gg	5.9	5.1	5.2	5.4	5.4	5.4	5.2	5.6	5.8	6.4
Plaster production	Gg	319.0	315.9	312.8	309.7	306.6	303.6	300.5	297.4	294.3	291.2

2A4a Ceramics	**Unit**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Fine ceramics production	Gg	C	C	C	C	C	C	C	C	C	C
Limestone use	Gg	C	C	C	C	C	C	C	C	C	C
Dolomite use	Gg	C	C	C	C	C	C	C	C	C	C
Soda use	Gg	C	C	C	C	C	C	C	C	C	C
Brick and tile production	Gg	959	945	875	859	1'023	1'086	1'065	975	865	701
2A4d Other											
Rock wool production	Gg	C	C	C	C	C	C	C	C	C	C
Other use of carbonates	Gg	7.0	7.8	8.0	7.1	6.4	7.3	7.0	7.0	7.4	6.6
Plaster production	Gg	288.1	285.0	290.5	295.9	301.4	326.7	322.6	314.1	295.3	293.4

2A4a Ceramics	**Unit**	**2010**	**2011**	**2012**	**2013**
Fine ceramics production	Gg	C	C	C	C
Limestone use	Gg	C	C	C	C
Dolomite use	Gg	C	C	C	C
Soda use	Gg	C	C	C	C
Brick and tile production	Gg	879	800	792	785
2A4d Other					
Rock wool production	Gg	C	C	C	C
Other use of carbonates	Gg	6.9	6.4	7.6	6.1
Plaster production	Gg	335.1	293.1	270.8	218.3

Other uses of soda ash (2A4b)

The main use of soda ash is in the glass production which is reported separately in source category 2A3 Glass production. A very small amount of soda ash is also applied in glazes of fine ceramics and is thus included in source category 2A4a Ceramics (see Table 4-10).

Other (2A4d)

Rock wool production (2A4d)

In Switzerland there is one single producer of rock wool. The plant uses carbonate containing raw materials like dolomite, basalt, cement and further additives.

All information of the rock wool production is documented in EMIS 2015/2A4d Steinwolle Produktion.

From 2013 onwards rock wool manufacturers are requested by law to report geogenic CO_2 emissions from carbonate containing raw material. This allows for the calculation of CO_2 emissions according to the Tier 3 method of the 2006 IPCC guidelines (vol. 3, 2.5 Other process uses of carbonates).

Methodology

The geogenic CO_2 emissions from rock wool production are determined by a Tier 3 method according to IPCC 2006 (vol. 3, chapter 2.5 Other process uses of carbonates). For rock wool production in Switzerland this results in the following formula:

CO_2 Emissions = $M_{\text{Rock wool}} \bullet EF_{\text{Rock wool}}$

Emission Factors

For rock wool production in Switzerland the CO_2 emisson factor is based on analytical measurements of the oxides (CaO, MgO, Na_2O, K_2O, MnO) of the carbonate containing raw materials and the product for the years 2005 to 2011and 2013. Based on these values the total geogenic CO_2 emissions are determined. Consequently the emission factor is specified as g/t rock wool. Since data on the carbonate content are missing for the years 1990 to 2004 and 2012 the mean value of the years 2005-2011 and 2013 is applied for these years.

The CO_2 emission factors are considered confidential; however, they are available to the reviewers.

Table 4-12 Geogenic CO_2 emission factors used for rock wool production and other carbonate uses, CO_2 fossil, NOx, CO, NMVOC and SO_2 emission factors for plaster production in g/t carbonate containing raw material and g/t product, respectively for 2013 (EMIS 2015/2A4d..).

2A4d Other	Unit	CO_2 geogenic	CO_2 fossil	NO_x	CO	NMVOC	SO_2
Rock wool production	g/t	C	NO	NO	NO	NO	NO
Other carbonate uses	g/t	523'880	NO	NO	NO	NO	NO
Plaster production	g/t rocks	NO	144	5.6	33	14.4	0.24

Table 4-13 In the confidential NIR the respective table with geogenic CO_2 emission factors for 1990-2013 used for rock wool production is separately reported and available to reviewers.

Activity Data

Activity data are based on industry data from the single rock wool production plant in Switzerland and regarded as confidential, however available to the reviewers upon request.

Other carbonate uses (2A4d)

Methodology

In 2014 an assessment was carried out in order to identify sources of CO_2 emissions from carbonate use for sulphur oxide removal and acid neutralization which were not considered in the Swiss greenhouse gas inventory so far (INFRAS 2015). The survey among selected potentially relevant industrial plants, industry associations, Swiss cantons and the Swiss customs administration (EZV) comprised the following substances: limestone ($CaCO_3$), dolomite ($CaMg(CO_3)_2$), sodium bicarbonate ($NaHCO_3$) and soda ash (Na_2CO_3).

Besides applications of calcium hydroxide and sodium hydroxide in flue gas treatement also a few applications of limestone and sodium bicarbonate could be identified in Switzerland. Limestone has been used in the cellulose production up to 2008, when the plant was closed and in one waste incineration plant up to 2005. Another waste incineration plant used sodium bicarbonate in 2013. These geogenic CO_2 emissions are therefore reported in the corresponding source categories, i.e. 1A1a Waste incineration plants and 1A2d Cellulose production.

Additionally, it was assumed, that all kind of applications of sodium bicarbonate could result in a complete conversion to CO_2. Since there is no production of sodium bicarbonate in Switzerland, the annual emissions can be estimated based on the net import by subtracting the amount that is already accounted for in another source category (i.e. 1A1a Waste incineration plants). These emissions are thus reported in source category 2A4d Other carbonate uses. Furthermore no application of soda ash or any other carbonate containing material in flue gas treatment was found.

Besides in flue gas treatment, limestone is also used to neutralize acid waste water in one chemical production plant. These emissions are reported in source category 2B10 Limestone pit.

Emission Factors

The emission factor is defined by the stoichiometry of sodium bicarbonate, see Table 4-12. A conversion factor of 100% is assumed.

Activity Data

The activity data correspond to the amount of sodium bicarbonate. The time series is based on the annual net imports of sodium bicarbonate reported by the Swiss customs administration (Eidgenössische Zollverwaltung, EZV 2014). Any application of sodium bicarbonate that can be assigned to another source category is subtracted from the total net import and reported in the corresponding source category. Thus the use of sodium bicarbonate in one waste incineration plant in 2013 has been subtracted and is reported in source category 1A1a. For activity data see Table 4-11.

Plaster production (2A4d)

Methodology

The emissions of CO_2, NO_x, CO, NMVOC and SO_2 from 2A4d Plaster production refer to emissions from blasting operations during the mining of gypsum, i.e. the raw material for plaster production. The emissions are calculated by multiplying the annual amount of processed rock by the emission factors. There are two plaster production sites in Switzerland.

Emission Factors

As there are no specific emission factors for gypsum mining, the emission factors for cement raw material mining are taken instead (with a rough estimate that 1.5 t of rocks are needed for 1 t of cement). This approach is documented in EMIS 2015/2A4d Gips-Produktion übriger Betrieb. For emission factors see Table 4-12.

Activity Data

The activity data of the annual amount of rocks processed in the plaster production are based on industry data and expert estimates as documented in EMIS 2015/2A4d Gips-Produktion übriger Betrieb (see Table 4-11).

4.2.3 Uncertainties and Time-Series Consistency

The uncertainty for CO_2 emissions in cement production (2A1) which is a key category regarding level and trend amounts to 2.8%. The uncertainty of CO_2 emissions was calculated following the steps in Table 3.2 in 2000 IPCC good practice guidance (IPCC 2000, p. 3.15). As CO_2 emissions are calculated based on plant level CaO and MgO contents of the clinker (Tier 2 approach) an uncertainty of 2% is assumed both for activity data and emission factor (step 3 in table 3.2).

The uncertainties for CO_2 emissions from source categories 2A2 and 2A3 are estimated to be low and thus amount to 2% (see Table 1-11 Semi-quantitative uncertainties for non-key categories).

For CO_2 emissions in source category 2A4 Other process uses of carbonates which is a key category regarding trend according to approach 1 and 2 an overall uncertainty of 51% and an uncertainty of 1.4% for activity data and 51% for the emission factor is taken.

Consistency: Time series for 2A Mineral industry are all considered consistent.

4.2.4 Source-Specific QA/QC and Verification

The general QA/QC measures are described in section 1.2.3.

For submission 2015 an assessment of the geogenic CO_2 emission factor from carbonates in brick and tile production has been conducted based on validated and verified monitoring data due to the Ordinance for the Reduction of CO_2 Emissions (Swiss Confederation 2012) (ongoing 2013-2015, FOEN).

For submission 2015 an assessment of carbonate use for sulphur oxide removal and acid neutralization was carried out (INFRAS 2015).

In submission 2012 the emission factor of category 2A1 used in the Swiss Inventory was compared to the corresponding emission factors of other countries (UNFCCC http://unfccc.int/di/FlexibleQueries.do) and to the IPCC default value (INFRAS 2012). Switzerland's factor lies in the midfield of the other countries; see chpt. 4.2.2.1.

In submission 2012 the emission factor of category 2A2 used in the Swiss Inventory was compared to the corresponding emission factors of other countries (UNFCCC http://unfccc.int/di/FlexibleQueries.do) and to the IPCC default value (INFRAS 2012). Switzerland's factor lies in the midfield of the other countries, see chpt. 4.2.2.1.

In submission 2012 the implied emission factor of category 2A4 used in the Swiss Inventory was compared to the corresponding emission factors of other countries (UNFCCC http://unfccc.int/di/FlexibleQueries.do) and to the IPCC default value if available (INFRAS 2012). Switzerland's factor lies beyond the other countries. The Swiss factor includes emissions from three different sources: fine ceramics, rock wool and brick and tile. The emissions in category 2A4 are dominated by the brick and tile production. The brick and tile industry does not report the input of carbonate containing raw materials but the annual amount of bricks and tiles produced only. Therefore the Swiss implied emission factor was calculated with respect to tonnes of product which is the reason for this low value. The Swiss brick and tile industry has determined in 2012 the carbonate content of the clay raw material at several pits. A first comparison with the carbonate content of clay from pits in other European countries confirms that the Swiss values are rather high.

4.2.5 Source-Specific Recalculations

- 2A1 Cement production: AD and EF of cement production (blasting operations) are now related to tons of clinker, and not cement as it was before. Therefore all data from 1990-2012 have been converted to this unit.

  The EF of fossil CO_2 and CO for cement production (blasting operations) have been corrected. They are taken from the Environmental Enforcement: Handbook, Emission Factors for Stationary Sources (SAEFL 2000).
- 2A3 Container glass production: the EF of geogenic CO_2 has been revised for 2005-2012. From 2005 onwards the EF values base now on effective carbonate contents in the raw material instead of cullet ratios wich are still used for the years 1990-2004.
- 2A3 Glass production (speciality tableware): the EF of geogenic CO_2 has been revised for 2012 based on the effective cullet ratio.
- 2A4a Brick and tile production: the AD for 2012 have been corrected due to a mistake in last year's submission.
- 2A4d Rockwool production: the EF of geogenic CO_2 has been revised for the entire time series based on new available data of the carbonate content in the raw material for the years 2005-2011.

- 2A4d Other process uses of carbonates: in source category 2A4d Other process uses of carbonates the CO_2 emissions from the use of ammonium bicarbonate are newly included in the inventory for the entire time period.

4.2.6 Source-Specific Planned Improvements

No source-specific improvements are planned.

4.3 Source Category 2B – Chemical Industry

4.3.1 Source Category Description

Source category 2B Chemical industry comprises process emissions from the production of ammonia, nitric acid, silicon carbide, ethylene, acetic acid, niacin, PVC (ceased in 1996) and sulphuric acid as well as from acid neutralization in a limestone pit.

Table 4-14 Specification of source category 2B Chemical industry. EMIS 2015/… refers to the internal documentation of the emission database and contains further references regarding specific AD and/or EF.

2B	Source	Specification	Data Source
2B1	Ammonia production	Emissions of CO_2 and NMVOC are reported in 2B8b Ethylene production	AD, EF: EMIS 2015/2B1 Ammoniak-Produktion
2B2	Nitric acid production	Emissions of N_2O and NOx from the production of nitric acid	AD, EF: EMIS 2015/2B2 Salpetersäure Produktion
2B3	Adipic acid production	Not occurring in Switzerland	
2B4	Caprolactam, glyoxal and glyoxilic acid production	Not occurring in Switzerland	
2B5	Carbide production	Emissions of CO_2, CH_4 and SO_2 from the production of silicon carbide	AD, EF: EMIS 2015/2B5 Graphit und Siliziumkarbid Produktion
2B6	Titanium dioxide production	Not occurring in Switzerland	
2B7	Soda ash production	Not occurring in Switzerland	
2B8	Petrochemical and carbon black production	Emissions of CO_2 and NMVOC from ethylene production. In Switzerland there is only ethylene production under this source category	AD, EF: EMIS 2015/2B8b ethylene production
2B9	Fluorochemical production	Not occurring in Switzerland	
2B10	Other	Emissions of CO_2, CH_4, CO and NMVOC from acetic acid production; CO_2 emissions from limestone pit and niacin production; NMVOC emissions from PVC production (ceased in 1996); SO_2 emissions from sulphuric acid production	AD, EF: EMIS 2015/2B10 Essigsäure-Produktion, EMIS 2015/2B10 Kalksteingrube, EMIS 2015/2B10 Niacin-Produktion, EMIS 2015/2B10 PVC-Produktion, EMIS 2015/2B10 Schwefelsäure-Produktion

4.3.2 Methodological Issues

4.3.2.1 Ammonia production (2B1)

Ammonia (NH_3) is produced in one single plant in Switzerland by catalytic reaction of nitrogen and synthetic hydrogen (see Figure 4-4). Ammonia is not produced in an isolated reaction plant but is part of an integrated production chain (see Figure 4-5).

The starting production process is the thermal cracking of liquefied petroleum gas (LPG) and light virgin naphtha yielding ethylene (ethene, C_2H_4), and a series of by-products such as e.g. synthetic hydrogen and methane, which are used as educts for further production steps. According to the Swiss ammonia producer it is not possible to split and allocate the emissions of the cracking process (CO_2 and NMVOC) to every single product such as, e.g., ethylene, acetylene (ethyne, C_2H_2), cyanic acid or ammonia. Therefore, all CO_2 and NMVOC emissions of the cracking process are allocated to the ethylene production and are reported under the category 2B8b Ethylene production. Thus, for source category 2B1 Ammonia production, CO_2 and NMVOC emissions are reported as included elsewhere (IE). All information on the ammonia production and the cracking process is documented in EMIS 2015/2B1 Ammoniak-Produktion and EMIS 2015/2B8b Ethen-Produktion, respectively.

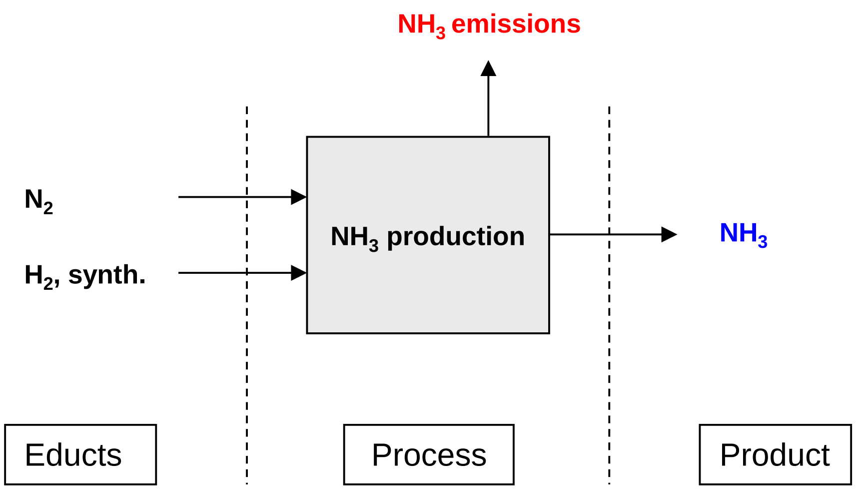


Figure 4-4 Process flow chart for the production of ammonia (NH_3) from nitrogen (N_2) and hydrogen (H_2, synth.). Hydrogen is derived from the thermal cracking process in the same plant (see Figure 4-5).

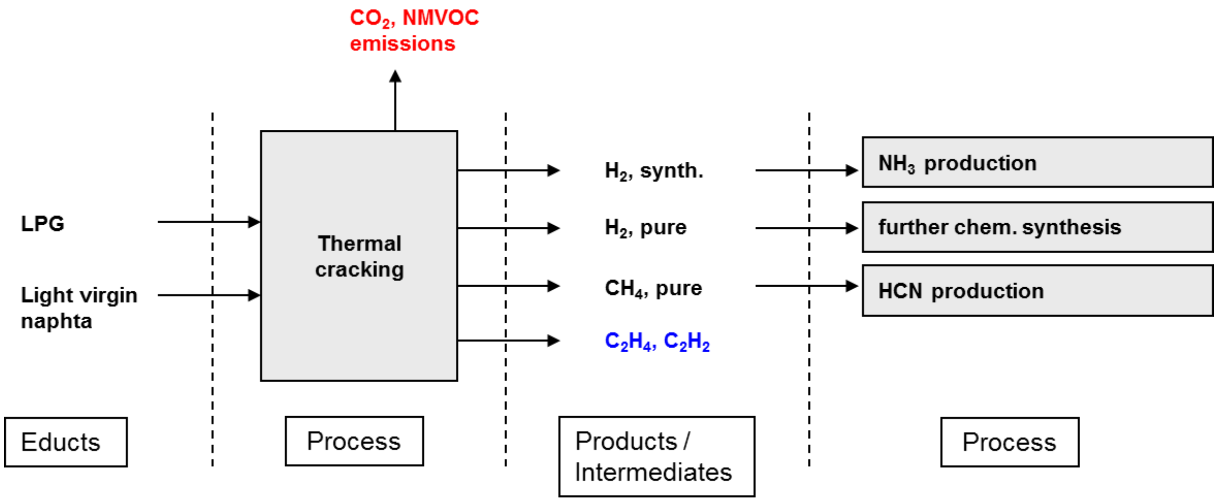


Figure 4-5 Process flow chart for the production of ethylene (C_2H_4) and acetylene (C_2H_2) by thermal cracking of liquefied petroleum gas (LPG) and light virgin naphta. The intermediate product H_2, synth. is used as educt in the ammonia production in the same plant (see Figure 4-4).

4.3.2.2 Nitric acid production (2B2)

In Switzerland there is one single plant producing nitric acid (HNO_3). Nitric acid is produced by catalytic oxidation of ammonia (NH_3) with air. At temperatures of 800°C nitric monoxide (NO) is formed. During cooling, nitrogen monoxide reacts with excess oxygen to form nitrogen dioxide (NO_2). The nitrogen dioxide reacts with water to form 60% nitric acid (HNO_3). Today, two types of processes are used for nitric acid production: single pressure or dual pressure plants. In Switzerland a dual pressure plant is installed.

During the process nitrous oxide (N_2O) can be formed as an unintentional by-product. In addition, also some nitrogen oxide (NOx) is produced. In the Swiss production plant abatement of NOx is done by selective catalytic reduction (SCR, installed in 1988) which reduces NOx to N_2 and O_2 (the SCR in this plant is also used for treatment of other flue gases and was not installed for the HNO_3 production specially). In 1990 an automatic control system for the dosing of ammonia to the SCR process was installed.

No additional abatement technique is installed to destroy N_2O. A decomposition of N_2O occurs, to some extent, simultaneously in the NOx reduction process. The production and abatement technology has essentially remained the same from 1990 to 2012. In 2013 a new catalyst was installed and the volume of the SCR-plant duplicated.

Methodology

The N_2O and NOx emissions from nitric acid production are determined by a Tier 2 method. The emissions are calculated by multiplying the annual nitric acid production output by the corresponding emission factors for N_2O and NOx emissions respectively.

Emission Factors

The N_2O and NOx emission factors for nitric acid production in Switzerland are based on measurements from the single nitric acid production plant. The measurement of N_2O was carried out in 2009 according to the guideline VDI-Richtlinie 2469/Blatt 1 (Messen gasförmiger Emissionen - Messen von Distickstoffmonoxid - Manuelles gaschromatographisches Verfahren) and is the only plant specific measurement of N_2O emissions. The test gas is sucked in via a heated titanium sensor and then treated with a solution of potassium permanganate and hydrogen peroxide in order to remove nitrogen oxides and further disturbing components. The N_2O concentration is then measured using a gas chromatograph with an electron capture detector. The measurement uncertainty is ± 20% (minimum ± 0.5 mg/m^3). On repeated enquires the plant confirmed that since a denitrification system and an automatic control system for the ammonia addition was installed in 1988 and 1990, respectively, no modification were made in the production line until 2012. Therefore a constant N_2O-emission factor is assumed for this time period. A new catalyst installed in 2013 reduced the N_2O emissions which are measured online by NDIR photometry from 2013 onwards.

The NOx emission factor is the mean value based on three plant specific measurements in 2007, 2009 and 2012. Since no modifications were made in the production line from 1990 to 2012 a constant emission factor for this time period is assumed. In 2013 the volume of the SCR-plant was duplicated. This modification together with the new catalyst in the production line slightly reduced the NOx emission factor. The values are documented in EMIS 2015/2B2 Salpetersäure Produktion. They are considered confidential, however, available to reviewers on request.

Table 4-15 Emission factors for N_2O and NOx for nitric acid production in Switzerland in kg/t nitric acid for 2013. Data refers to 100% nitric acid (EMIS 2015/2B2 Salpetersäure Produktion).

2B2 Nitric acid production	Unit	N_2O	NO_x
	kg/t	C	C

Activity Data

Activity data on annual production of nitric acid (100%) are provided on a yearly basis by the Swiss production plant for the entire time period 1990-2013. The data are confidential but available to reviewers (see EMIS 2015/2B2 Salpetersäure Produktion).

Table 4-16 In the confidential NIR the respective table with activity data on nitric acid production in Switzerland is separately reported and available to reviewers.

4.3.2.3 Carbide production (2B5)

In Switzerland there is one single plant producing carbide. The plant produces silicon carbide which is used in abrasives, refractories, metallurgy and anti-skid flooring. The Swiss silicon carbide is produced in an electric furnace at temperatures above 2000ºC using the Acheson process. The starting materials are quartz sand (SiO_2), petroleum coke and anthracite (C) which yield silicon carbide (SiC) and carbon monoxide (CO). The CO is converted to CO_2 in excess oxygen and released to the atmosphere. Petroleum coke and anthracite – although to a lower portion – may contain volatile organic compounds which can form methane (CH_4) as an unintended by-product. There is no abatement techniques installed which could capture the CO_2 or CH_4 emissions.

Methodology

The CO_2, CH_4 and SO_2 emissions from silicon carbide production are determined by a Tier 2 method. The emissions are calculated by multiplying the annual silicon carbide production output by the corresponding emission factors for CO_2, CH_4 and SO_2 emissions, respectively.

Emission Factors

The CO_2, CH_4 and SO_2 emission factors are considered confidential, however, available to reviewers on request. The values are partly based on measurements and data from the single silicon carbide production plant and are documented in EMIS 2015/2B5 Graphit und Siliziumkarbid Produktion.

Table 4-17 In the confidential NIR the respective table with CO_2 emission factors for carbide production in kg/t silicon carbide in Switzerland for the entire time series is separately reported and available to reviewers.

Table 4-18 In the confidential NIR the emission factors for CO_2, CH_4 and SO_2 for carbide production in kg/t silicon carbide in Switzerland are separately reported for 2013 and available to reviewers.

Activity Data

Activity data on annual production of silicon carbide are provided on a yearly basis from 1997 onwards by the Swiss production plant. For the time period 1990-1996 activity data are based on industry data for 1990 and 1995 and interpolated values in between. The data are confidential but available to reviewers on request (see EMIS 2015/2B5 Graphit und Siliziumkarbid Produktion).

Table 4-19 In the confidential NIR the respective table with activity data on silicon carbide production in Switzerland is separately reported and available to reviewers.

4.3.2.4 Petrochemical and carbon black production (2B8)

Ethylene (2B8b)

Ethylene (ethene, C_2H_4) is produced by a single plant in Switzerland by thermal cracking of liquefied petroleum gas (LPG) and virgin naphta. Ethylene is not produced in an isolated process but is co-processed together with several other products such as H_2, CH_4, and C_2H_2

(see flow chart in Figure 4-5 in section 4.3.2.1). From the thermal cracking process emissions of CO_2 and NMVOC are released. They are both allocated entirely to the production of ethylene which is the first product within the integrated production chain. CH_4 emissions to atmosphere do not occur since CH_4 is completely used as an educt in the downstream production of cyanic acid (HCN) in the same facility (again, see Figure 4-5 and for further information see EMIS 2015/2B8b Ethen-Produktion). Therefore CH_4 emissions are reported as NA for ethylene production and only CO_2 and NMVOC emissions are reported.

Methodology

The CO_2 and NMVOC emissions from ethylene production are determined by a country-specific approach. The emissions are calculated by multiplying the annual ethylene production output by the corresponding emission factors for CO_2 and NMVOC emissions respectively.

Emission Factors

The CO_2 and NMVOC emission factors for ethylene production are based on industry data from the single ethylene production plant in Switzerland. Annual emission data were only available from the year 2000 onwards. For the period 1990-1999 a constant value, i.e. the mean value of the years 2000-2009 was assumed. The emission factors for ethylene production are considered confidential; however, they are available to reviewers on request.

Table 4-20 Emission factors for CO_2 and NMVOC in ethylene production, NMVOC in acetic acid production, CO_2 in limestone pit and niacin production and SO_2 in sulphuric acid production for 2013 in kg/t product (EMIS 2015/2B8b Ethen-Produktion, EMIS 2015/2B10 Essigsäure-Produktion, EMIS 2015/2B10 Kalksteingrube, EMIS 2015/2B10 Niacin-Produktion and EMIS 2015/2B10 Schwefelsäure-Produktion).

	Unit	CO_2	NMVOC	SO_2
2B8 Petrochemical and carbon black production				
2B8b Ethylene	kg/t	C	C	NA
2B10 Other				
Acetic acid production	kg/t	NA	C	NA
Limestone pit	kg/t	C	NA	NA
Niacin production	kg/t	C	NA	NA
Sulphuric acid production	kg/t	NA	NA	C

Table 4-21 In the confidential NIR the respective table with emission factors for CO_2 in ethylene production for the entire time series is separately reported and available to reviewers.

Activity Data

Activity data on the annual production of ethylene are provided on a yearly basis by the single ethylene production plant in Switzerland for the entire time period 1990-2013. The data are considered confidential but available to reviewers on request.

Table 4-22 Activity data for the production of ethylene, acetic acid, niacin, PVC and sulphuric acid as well as for limestone pit in Switzerland for the period 1990-2013 in Gg (EMIS 2015/2B8b Ethen-Produktion, EMIS 2015/2B10 Essigsäure-Produktion, EMIS 2015/2B10 Kalksteingrube, EMIS 2015/2B10 Niacin-Produktion, EMIS 2015/2B10 PVC-Produktion and EMIS 2015/2B10 Schwefelsäure-Produktion).

	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
2B8 Petrochemical and carbon black production											
2B8b Ethylene	kt	C	C	C	C	C	C	C	C	C	C
2B10 Other											
Acetic acid production	kt	30	29	29	28	28	27	27	26	26	25
Limestone pit	kt	C	C	C	C	C	C	C	C	C	C
Niacin production	kt	C	C	C	C	C	C	C	C	C	C
PVC production	kt	43	43	43	43	43	43	7	0	0	0
Sulphuric acid production	kt	C	C	C	C	C	C	C	C	C	C

	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
2B8 Petrochemical and carbon black production											
2B8b Ethylene	kt	C	C	C	C	C	C	C	C	C	C
2B10 Other											
Acetic acid production	kt	24	14	11	10	9	8	8	9	18	28
Limestone pit	kt	C	C	C	C	C	C	C	C	C	C
Niacin production	kt	C	C	C	C	C	C	C	C	C	C
PVC production	kt	0	0	0	0	0	0	0	0	0	0
Sulphuric acid production	kt	C	C	C	C	C	C	C	C	C	C

	Unit	2010	2011	2012	2013
2B8 Petrochemical and carbon black production					
2B8b Ethylene	kt	C	C	C	C
2B10 Other					
Acetic acid production	kt	20	18	12	C
Limestone pit	kt	C	C	C	C
Niacin production	kt	C	C	C	C
PVC production	kt	0	0	0	0
Sulphuric acid production	kt	C	C	C	C

4.3.2.5 Other (2B10)

Source category Other (2B10) comprises emissions from production of acetic acid, sulphuric acid, niacin and PVC (ceased in 1996) as well as from limestone pits.

Acetic acid production (2B10)

In Switzerland there is only one plant producing acetic acid (CH_3COOH) remaining in 2013 after the other one stopped its production by the end of 2012. The still existing plant emits NMVOC only whereas from the latter one also emissions of CO_2, CH_4 and CO have occured.

Methodology

In order to determine emissions of CO_2, CH_4, CO and NMVOC from acetic acid a country-specific approach is used. The emissions are calculated by multiplying the annual production of acetic acid by the corresponding emission factor.

Emission Factors

The emission factors for CO_2, CH_4, CO and NMVOC from acetic acid production in Switzerland are country specific and based on measurement data from industry and expert estimates documented in EMIS 2015/2B10 Essigsäure-Produktion (see Table 4-20 for NMVOC).

Usually the process emissions in the plant which stopped its production in the end of 2012 had been treated in a flue gas incineration. Thus, the reported emissions of CH_4, CO and NMVOC only occured in case of malfunction resulting in strongly fluctuating plant-specific emission factors. In addition the resulting implied emission factors based on the emissions of both plants are modulated by considerable production fluctuations of one of the plants from 2000 onwards.

The emission factors for acetic acid production are confidential but available to reviewers on request.

Table 4-23 In the confidential NIR the respective table with emission factors for CO_2 and CH_4 in acetic acid production for the entire time series are separately reported and available to reviewers.

Activity Data

The annual amount of produced acetic acid is based on data from industry and expert estimates documented in EMIS 2015/2B10 Essigsäure-Produktion (see Table 4-22). The data for acetic acid production in 2013 (only one manufacturer remaining) are confidential but available for reviewers.

Limestone pit (2B10)

In one chemical plant acids are neutralized in a so-called limestone pit yielding geogenic CO_2 emissions. These emissions are newly reported for the entire time period 1990-2013 in this year’s submission of the inventory.

Methodology

The CO_2 emissions from the limestone pit are determined by a country-specific approach. The emissions are calculated by multiplying the annual calcium carbonate use for acid neutralization by the corresponding emission factor for CO_2 emissions.

Emission Factors

The CO_2 emission factor is considered confidential but available to reviewers on request.

Activity Data

Since no data are available for limestone pit for the time period 1990-1998, the annual activity is derived from the average annual consumption between 1999 and 2013. The annual activity data from 1999-2013 are the actual annual consumption of calcium carbonate reported by the manufacturer and documented in EMIS 2015/2B10 Kalksteingrube. Activity data is considered confidential but available to reviewers on request.

Niacin production (2B10)

For submission 2015 the CO_2 emissions from niacin production of the single manufacturer in Switzerland are reported for the first time. CO_2 is released in the last reaction step of the niacin production.

Methodology

In order to determine emissions of CO_2 from niacin production, a country-specific approach is used. The emissions are calculated by multiplying the annual production of niacin by the corresponding emission factor.

Emission Factors

The CO_2 emission factor is country-specific and based on data provided by the single Swiss manufacturer documented in EMIS 2015/2B10 Niacin-Produktion. The emission factor is considered confidential but available to reviewers on request.

Activity Data

Activity data of annual niacin production were provided by the Swiss production plant for the entire time period as documented in EMIS 2015/2B10 Niacin-Produktion. Activity data are considered confidential but available to reviewers on request.

PVC and sulphuric acid production (2B10)

Sulphuric acid (H_2SO_4) is produced by one plant only in Switzerland. From this production process SO_2 is emitted. Until 1996 also PVC was produced in Switzerland releasing NMVOC emissions.

Methodology

In order to determine SO_2 and NMVOC emissions from sulphuric acid and PVC production, respectively, a country-specific approach is used. The emissions are calculated by multiplying the annual production by the corresponding emission factor.

Emission Factors

The emission factor for SO_2 from sulphuric acid production in Switzerland is plant specific and based on measurement data from industry and expert estimates documented in EMIS 2015/2B10 Schwefelsäure-Produktion. The SO_2 emission factor is confidential but available to reviewers on request.

For PVC production the NMVOC emission factor was based on industry information and expert estimates (EMIS 2015/2B10 PVC-Produktion).

Activity Data

The annual amount of sulphuric acid and PVC produced is based on data from industry and expert estimates documented in EMIS 2015/2B10 Schwefelsäure-Produktion and EMIS 2015/2B10 PVC-Produktion (see Table 4-22). The activity data for sulphuric acid production are confidential but available to reviewers on request.

4.3.3 Uncertainties and Time-Series Consistency

The uncertainties for CO_2 and CH_4 in source category 2B are both estimated to be medium, (see Table 1-11 Semi-quantitative uncertainties for non-key categories) resulting in a relative uncertainty of 10% for CO_2 and of 30% for CH_4. For N_2O emissions from 2B2 Nitric acid production, which has been a key category in previous submissions, the uncertainty was calculated to be 41%.

Consistency: Time series for 2B Chemical industry are all considered consistent.

4.3.4 Source-Specific QA/QC and Verification

The general QA/QC measures are described in section 1.2.3.

In submission 2012 the N_2O emission factor of source category 2B2 Nitric Acid Production used in the Swiss Inventory was compared to the corresponding emission factors of other countries (UNFCCC http://unfccc.int/di/FlexibleQueries.do) and to the IPCC default value (INFRAS 2012). Switzerland's factor lies in the midfield of the other countries; see chpt. 4.3.2.2.

4.3.5 Source-Specific Recalculations

2B10 Other: CO_2 emissions from two new source categories 2B10 niacin production and 2B10 limestone pit are included in the inventory for the entire time period 1990-2013.

2B10 Other: The SO_2 emission factor from 2B10 Sulphuric acid production has been revised for 1990-2009 based on the updated EF value for 2013.

4.3.6 Source-Specific Planned Improvements

No source-specific improvements are planned.

4.4 Source Category 2C – Metal Industry

4.4.1 Source Category Description

Approach 1 Key category 2C3

CO_2 emissions from Aluminium production (trend).

PFC emissions from Aluminium production (trend).

Source category 2C Metal industry comprises process emissions from the production of iron, steel and aluminium, from the use of SF_6 in aluminium and magnesium foundries, as well as from non-ferrous metal foundries and battery recycling.

Table 4-24 Specification of source category 2C Metal industry. EMIS 2015/… refers to the internal documentation of the emission database and contains further references regarding specific AD and/or EF.

2C	Source	Specification	Data Source
2C1	Iron and steel production	Emissions of CO_2, NOx, CO, NMVOC and SO_2 from the production of iron and steel	AD, EF: EMIS 2015/2C1 Eisengiessereien Elektroschmelzofen/übriger Betrieb, EMIS 2015/2C1 Stahl-Produktion Elektroschmelzöfen/übriger Betrieb
2C2	Ferroalloys production	Production is not occuring in Switzerland	
2C3	Aluminium production	Emissions of PFC, CO_2, NOx, CO, NMVOC, and SO_2 from the production of aluminium (ceased in 2006)	AD: EMIS 2015/2C3 Aluminium Produktion EF for PFC: Industry Data EF other gases: EMIS 2015/2C3 Aluminium Produktion
2C4	Magnesium production	Emissions from use of SF_6 in magnesium foundries (emissions from use of SF_6 in aluminium foundries included)	AD: Industry Data (Carbotech 2015) EF: IPCC 2006
2C5	Lead production	Not occurring in Switzerland	
2C6	Zinc production	Not occurring in Switzerland	
2C7	Other	Emissions of CO and NMVOC from non-ferrous metal foundries Emissions of CO_2, NOx, CO and SO_2 from battery recycling	AD, EF: EMIS 2015/2C7 Buntmetallgiessereien Elektroöfen AD, EF: EMIS 2015/2C7 Batterie-Recycling

4.4.2 Methodological Issues

4.4.2.1 Iron and steel production (2C1)

There is no primary iron and steel production in Switzerland. Only secondary steel production occurs, which is steel production from recycled steel scrap. After closing down of two steel plants in 1994 there remain two plants in Switzerland. Both plants use electric arc furnaces (EAF) with a carbon electrode for melting the steel scrap. During the melting process CO_2 emissions occur mainly from scrap, electrodes and carburization coal whereas the produced steel, filter dust and slag act as carbon sinks. Precursors such as NOx, CO, NMVOC and SO_2 occur as well.

In Switzerland no production of pig iron occurs but iron is processed in foundries only. Today there exist about 14 iron foundries in Switzerland. About 75% of the iron is processed in induction furnaces and 25% in cupola furnaces. From induction furnaces only precursors emerge. From cupola furnaces also CO_2 emissions arise. Those CO_2 emissions are accounted for in source category 1A2a.

Methodology

For determination of CO_2 emission from iron and steel production a mixture of a Tier 2 and a Tier 3 method according to IPCC 2006 (vol. 3, chapter 4.2 Iron & steel and metallurgical coke production) is used since the submission 2014. For the years 2005-2011 and 2013 plant specific data on the carbon mass balance is available due to legal obligations from the Ordinance for the Reduction of CO_2 Emissions (Swiss Confederation 2012) (tier 3). From this information data for the other years are interpolated for calculating an implied emission factor.

For steel production in Switzerland this results in the following formula:

$$E_{CO2,\ non\text{-}energy} = EAF \bullet EF_{EAF}$$

whereas EAF is the quantity of EAF crude steel produced in tonnes and EF_{EAF} the emission factor in tonnes CO_2/tonne steel produced. The same formula is also applied to calculate precursors from iron and steel production. No CH_4 emissions occur in the Swiss EAF process.

Emission Factors

The emission factors for iron and steel production in Switzerland are country-specific and are based on measurement data from industry and expert estimates documented in EMIS 2015/2C1 Eisengiessereien Elektroschmelzofen/übriger Betrieb, EMIS 2015/2C1 Stahl-Produktion Elektroschmelzöfen and EMIS 2015/2C1 Stahlwerke Walzwerke.

The electrode consumption in the two Swiss plants differs.. For the calculations all carbon sources (graphite electrodes, steel scrap, alloy coal, etc.) and carbon sinks (steel, filter dust and slag) for the years 2005-2011 and 2013 were taken into account. Based on these carbon balances mean plant specific CO_2 emission factors result. The plant-specific figures are considered confidential but available to reviewers on request. Thus the reported CO_2 emission factor for Swiss steel industry is the production-weighted average for the time period 1990–2013 (see Table 4-25).

Table 4-25 CO_2 emission factor of electric arc furnaces in 2C1 Steel production for the period 1990-2013 in kg/t (EMIS 2015/2C1 Stahl-Produktion Elektroschmelzöfen).

2C1 Steel production	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2	kg/t	8.3	8.2	8.1	8.1	8.1	8.0	8.0	7.8	7.5	7.5

2C1 Steel production	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2	kg/t	7.7	7.7	7.8	7.9	7.8	8.8	9.1	8.5	6.8	6.8

2C1 Steel production	Unit	2010	2011	2012	2013
CO_2	kg/t	7.6	7.1	7.9	8.4

Table 4-26 Emission factors for NOx, CO and NMVOC in iron production, for CO_2, NOx, CO, NMVOC and SO_2 in steel production, for CO and NMVOC in non-ferrous metal productionand for CO_2, NOx, CO and SO_2 in battery recycling for 2013 (EMIS 2015/2C1 Eisengiessereien Elektroschmelzofen/übriger Betrieb, EMIS 2015/2C1 Stahl-Produktion Elektroschmelzöfen and EMIS 2015/2C1 Stahlwerke Walzwerke, 2015/2C7 Buntmetallgiessereien Elektroöfen and EMIS 2015/2C7 Batterie-Recycling).

2C Metal industry	Unit	CO_2	NO_x	CO	NMVOC	SO_2
2C1 Iron production	kg/t	NA	0.01	4.1	4	NA
2C1 Steel production	kg/t	8.4	0.19	0.8	0.1	0.017
2C7a Non-ferrous metals	kg/t	NA	NA	0.24	0.05	NA
2C7c Battery recycling	kg/t	560	0.88	1.2	NA	0.01

Activity Data

Activity data on annual production of iron and steel are provided on a yearly basis by the Swiss production plants and the foundry association. Data is given in the following table:

Table 4-27 Production of iron, steel, aluminium and non-ferrous metals as well as amount of batteries recycled in Switzerland for the period 1990-2013 in Gg (EMIS 2015/2C1 Eisengiessereien Elektroschmelzofen/ übriger Betrieb, EMIS 2015/2C1 Stahl-Produktion Elektroschmelzöfen, EMIS 2015/2C3 Aluminium Produktion, EMIS 2015/2C7 Batterie-Recycling and 2015/2C7 Buntmetallgiessereien Elektroöfen).

2C Metal industry	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
2C1 Iron production	Gg	170	140	136	110	115	130	111	114	123	122
2C1 Steel production	Gg	1'108	1'155	1'245	1'276	1'230	716	738	789	880	918
2C3 Aluminium production	Gg	87	82	75	36	24	21	27	27	32	34
2C7a Non-ferrous metals	Gg	55	56	57	58	59	60	65	66	68	69
2C7c Battery recycling	Gg	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0

2C Metal industry	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
2C1 Iron production	Gg	120	105	80	73	67	67	67	72	78	49
2C1 Steel production	Gg	1'022	1'048	1'125	1'143	1'226	1'159	1'254	1'267	1'315	935
2C3 Aluminium production	Gg	36	36	40	44	45	45	12	0	0	0
2C7a Non-ferrous metals	Gg	70	60	49	43	38	33	30	28	21	15
2C7c Battery recycling	Gg	3.0	3.0	3.0	2.9	3.3	2.8	2.4	2.4	2.5	3.4

2C Metal industry	Unit	2010	2011	2012	2013
2C1 Iron production	Gg	53	61	46	45
2C1 Steel production	Gg	1'218	1'322	1'252	1'231
2C3 Aluminium production	Gg	0	0	0	0
2C7a Non-ferrous metals	Gg	20	12	18	7
2C7c Battery recycling	Gg	3.3	2.4	2.4	2.3

4.4.2.2 Aluminium production (2C3)

Methodology

The last production site for primary aluminium in Switzerland closed down in April 2006. Both CO_2 and PFC emissions of former years were based on a country-specific approach. For PFC emissions a more specific Tier 3 approach with facility-specifc data according to the 2006 IPCC Guidelines (IPCC 2006) was used. Operating smelter emissions have been monitored periodically by the industry for selected years. The emissions were calculated by multiplying annual production by emission factors.

FOEN imports statistics indicate SF_6 imports for the aluminium industry, referring to cleaning process in foundries. The 2006 IPCC Guidelines mention use of SF_6 in Aluminium production for magnesium alloys on a low scale but do not provide further information for evaluation. The evaluation and related information on methodology, activity data and emissions factors are included in 2C4 Magnesium production.

Emission Factors

The emission factor for CO_2 per ton of aluminium is country-specific. It is based on measurements and data from industry and expert estimates, documented in EMIS 2015/2C3 Aluminium Produktion. For CO_2 emissions from aluminium production, an emission factor of 1.6 ton CO_2 per ton of aluminium is used (EMIS 2015/2C3 Aluminium Produktion). This CO_2 stems from the oxidation of the anode in the electrolysis process. The value is based on an estimate of the amount of anode material used. In Switzerland only pre-backed anodes are used. The emissions for CO_2 are calculated with 0.43 tons of anode per ton of aluminium; it is assumed that the anode consists completely of carbon and that it is fully oxidized during the process (value from Swiss foundries, value for 1990, assumed to be constant over the time series).

For PFC emissions from aluminium production, operating smelter EFs have been monitored periodically by the industry for selected years. The only Swiss factory provided own measurements for 1990, 1999 and 2000 yielding smaller EFs than the European average (by factors of 3.9, 4.7 and 5.1, respectively) (Alcan 2003). The comparison with these data and data from IAI (2005) on global PFC emissions from aluminium production showed that the emissions from the smelter in Switzerland are lower by a factor of about 4. This seems to be plausible because they used point feed prebake (PFPB) technology which is known for the lowest emissions per tonne of aluminium. Therefore a "general reduction factor" of 4 for both PFC gases (CF_4 and C_2F_6) is adopted based on the average European values as reported from the European Aluminium Association (Alcan 2002) for the years with no measured emission data available. The resulting emission factors for Switzerland are still within the uncertainty range according to the 2006 IPCC Guidelines (variations by a factor 10 using same technologies). In order to calculate the emissions factors for the years 2001 to 2006 – without any measurements in Switzerland – the data has been interpolated from the European data. E.g. for the year 2006 a value of 0.035 kg PFC/tAL, results with a European average emission factor of 0.14 kg PFC/tAL and a reduction factor of 4. For the ratio of CF_4 to C_2F_6 a value of 90% to 10% is applied. As it was not possible to perform industry independent measurements, and because of the fact that aluminium production was closed in 2006 it is not possible to redo any measurements or to collect any information about the process details retroactively. The emission factors have decreased by a factor of about 4.9 between 1990 and 2006 due to technical efforts to reduce emissions (Alcan 2003).

The factors according to Table 4-28 are used. The large difference between the emission factors of the year 1999 and 2000 is based on measured data given by the company.

Table 4-28 PFC emissions factors for aluminium production in Switzerland. Aluminium production in Switzerland ceased in the year 2006, and no emissions ocurred thereafter.

Gas	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CF_4	kg/t	0.1530	0.1373	0.1215	0.1058	0.0900	0.0833	0.0765	0.0698	0.0630	0.0540
C_2F_6	kg/t	0.0170	0.0153	0.0135	0.0118	0.0100	0.0093	0.0085	0.0078	0.0070	0.0060

Gas	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CF_4	kg/t	0.0360	0.0360	0.0360	0.0360	0.0338	0.0315	0.0315	NO	NO	NO
C_2F_6	kg/t	0.0040	0.0040	0.0040	0.0040	0.0038	0.0035	0.0035	NO	NO	NO

Gas	Unit	2010	2011	2012	2013
CF_4	kg/t	NO	NO	NO	NO
C_2F_6	kg/t	NO	NO	NO	NO

Activity Data

In 2006 the last production site of aluminium in Switzerland was closed. Activity data on aluminium production from 1997 to 2006 are based on annual data published by the Swiss Aluminium Association. For earlier years, the data were provided directly by the aluminium industry. Activity data for aluminium production in Switzerland are given in Table 4-27.

4.4.2.3 Magnesium production (2C4)

Use of SF_6 in aluminium and magnesium foundries (2C4)

The use of SF_6 in aluminium foundries (2C3) has been included here (a use of SF_6 in aluminium production related to magnesium alloys is mentioned in the 2006 IPCC Guidelines).

Methodology

SF_6 is used in aluminium and magnesium foundries in the cleaning process as inert gas to fill casting forms. The Swiss Foundry Association (GVS) has not provided information on emission factors and hence a Tier 2 based approach is used. The inventory data on SF_6 used in aluminium and magnesium foundries (2C3/2C4) are based on the total imported amount of SF_6 for foundries according to the import statistics. It is assumed that the total imported amount is emitted within one year. For the inventory of any particular year the mean value of the imports in the present and the previous year is used to account for possible time lag between import and consumption (e.g. for 2013 inventory the mean value of 2012 and 2013 import data are used).

Emission Factors

There are no measurements of SF_6 emissions available to identify the fraction of SF_6 destroyed or transformed in the process. For SF_6 used in aluminium and magnesium foundries (2C3/2C4) it is assumed that the total imported amount is emitted (2006 IPCC Guidelines default emission factor of 1000 kg per ton of imported substance).

Activity Data

Activity data on SF_6 used in aluminium and magnesium foundries (2C3/2C4) are based on import data from FOEN statistics. For the activity data of any particular year the mean value of the imports in the present and the previous year is used to account for possible time lag between import and consumption (e.g. for 2013 the mean value of 2012 and 2013 import data are used). SF_6 is used in Swiss aluminium and magnesium foundries since 1997. There have been two magnesium foundries known to be using SF_6. In 2007 one of them closed down production which led to a reduction in activity data for magnesium foundries by 25% from 2007 to 2008. The remaining magnesium foundry reported activity data for 2008 to 2013 to the SWISSMEM statistics. The fact that only one magnesium foundry uses SF_6 was confirmed by a survey which has been carried out in 2011 within members of the Swiss Foundry Association (GVS). SF_6 has not been used in aluminium foundries in Switzerland since 2011. The amount of imported SF_6 for cleaning processes in former years is extrapolated from an estimated value given in the year 2003 by an import company. Details on the imported amount are not available for later years. A steady decrease since 2003 is assumed for the import of SF_6 used for aluminium cleaning. This assumption is based on the above mentioned survey and on information which was obtained on applications within the category ‘others’ from FOEN import statistics, indicating that decreasing amounts of SF_6 are used for aluminum cleaning.

4.4.2.4 Other (2C7)

Battery recycling and non-ferrous metal foundries (2C7)

There is one battery recycling plant in Switzerland. The recycling is done by applying the Sumitomo process. The batteries are first pyrolised at temperatures of 700°C in a reducing atmosphere in a shaft kiln. The gas with the carbonised components then goes to a post-combustion step where it is completely oxidised at temperatures of 1000°C. The flue gas is then led to flue gas cleaning. The metal fraction from the pyrolysis goes to a melting furnace where it is reduced by addition of coal and magnesium oxide. As reducing agent coke and Carburit is used.

In Switzerland there are one large company and several small plants operating non-ferrous metal foundries producing mainly copper alloys. During the melting process emissions of CO and NMVOC occur.

Methodology

To determine emissions of CO_2, NO_x, CO and SO_2 from battery recycling and of CO and NMVOC from non-ferrous metal foundries, a country-specific approach is used. The emissions are calculated by multiplying the annual amount of recycled batteries and produced non-ferrous metals by the corresponding emission factors.

Emission Factors

The emission factors of CO_2, NO_x, CO and SO_2 from battery recycling and of CO and NMVOC from non-ferrous metal foundries in Switzerland are country-specific and based on measurements from industry and expert estimates documented in EMIS 2015/2C7 Batterie-Recycling and 2015/2C7 Buntmetallgiessereien Elektroöfen (see Table 4-26).

Activity Data

The annual amount of recycled batteries and produced non-ferrous metals in Switzerland is reported from industry and the foundry association as documented in EMIS 2015/2C7 Batterie-Recycling and 2015/2C7 Buntmetallgiessereien Elektroöfen (see Table 4-27).

4.4.3 Uncertainties and Time-Series Consistency

The uncertainty of CO_2 emissions in 2C1 Iron and steel production amounts to 40.3 %. Production data of the steel industry have a high confidence and its uncertainty is estimated at 5% (EMIS 2015/2C1 Stahl-Produktion Elektroschmelzöfen). The uncertainty for the CO_2 emission factor is estimated at 40% (EMIS 2015/2C1 Stahl-Produktion Elektroschmelzöfen).

For the emission of CO_2 and PFC 2C3 Aluminium production which is a key category for both gases combined uncertainties of 10% and 9%, respectively are determined. The uncertainties of the emission factor and activity data are estimated at 7.1% and 6.4%, respectively for both, CO_2 and PFC.

For the emissions of SF_6 from the use in 2C4 Magnesium production an uncertainty of 36.5% is assumed based on a Monte Carlo simulation (Carbotech 2015).

The uncertainty of CO_2 emissions from source category 2C7 Other is estimated to be medium (see Table 1-11, semi-quantitative uncertainties for non-key categories) and thus amounts to 10%.

Consistency: Time series for 2C Metal industry are all considered consistent.

4.4.4 Source-Specific QA/QC and Verification

The general QA/QC measures are described in section 1.2.3.

For source category 2C1 Iron and steel production reassessment of CO_2 emission factor from electric arc furnaces in secondary steel production has been conducted based on plant specific carbon mass balance data which have been validated and verified within the obligations of the Ordinance for the Reduction of CO_2 Emissions (Swiss Confederation 2012) (FOEN, internal documentation 2013).

For source category 2C4 Magnesium production the data received from SWISSMEM and import firms have been checked for double counting.

4.4.5 Source-Specific Recalculations

2C3 Aluminium production, 2C4 Magnesium production: following the 2006 IPCC Guidelines new GWP values for SF_6 and PFC have been applied for the entire time period 1990 to 2013.

4.4.6 Source-Specific Planned Improvements

No source-specific improvements are planned.

4.5 Source Category 2D – Non-energy Products from Fuels and Solvent Use

4.5.1 Source Category Description

Source category 2D Non-energy products from fuels and solvent use comprises process emissions from lubricant and paraffin wax use, NMVOC emissions from coating applications, degreasing, dry cleaning as well as production and processing of chemical products, precursor emissions from road paving with asphalt and asphalt roofing as well as emissions from urea use in SCR catalysts of diesel engines (heavy motor vehicles). In addition 2D includes CO_2 emissions resulting from post-combustion of NMVOC in exhaust gases from coating applications, degreasing, dry cleaning as well as production and processing of chemical products .

Table 4-29 Specification of source category 2D Non-energy products from fuels and solvent use. EMIS 2015/… refers to the internal documentation of the emission database and contains further references regarding specific AD and/or EF.

2D	Source	Specification	Data Source
2D1	Lubricant use	Emissions of CO_2 from primary usage of lubricants in machinery and vehicles	AD: EV 2014, EMIS 2015/2D1 EF: 2006 IPCC, EMIS 2015/2D1
2D2	Paraffin wax use	Emissions of CO_2 from primary usage of paraffin waxes	AD: EV 2014, EMIS 2015/2D2 EF: 2006 IPCC, EMIS 2015/2D2
2D3	Other	Emissions of NMVOC from paint application in households, industry and construction; Emissions of CO_2 and NMVOC from degreasing; dry cleaning; cleaning of electronic components; cleaning of parts in metal processing; other industrial cleaning; Emissions of CO_2 and NMVOC from handling and storage of solvents; fine chemical production; production of pharmaceuticals; manufacturing of paint, inks, glues, adhesive tape, rubber; processing of PVC, polystyrene foam, polyurethane and polyester; Emissions of CO_2 from post-combustion of NMVOC; Emissions of NMVOC from road paving; Emissions of CO and NMVOC from asphalt roofing; Emissions of CO_2 from urea-based catalysts	AD, EF: EMIS 2015/2D3a AD, EF: EMIS 2015/2D3b Strassenbelagsarbeiten, EMIS 2015/2D3c Dachpappenproduktion und Verlegung AD, EF: EMIS 2015/2D3d Urea (AdBlue) Einsatz Strassenverkehr

4.5.2 Methodological Issues

4.5.2.1 Lubricant use (2D1)

Lubricants are mostly used in industrial and transportation applications. They can be subdivided into motor oils, industrial oils and greases, which differ in terms of physical characteristics, commercial applications and environmental fate.

The use of lubricants in engines is primarily for their lubricating properties and associated CO_2 emissions are therefore considered as non-combustion emissions reported in 2D1 Lubricant use.

Methodology

For the calculation of CO_2 emissions from oxidation of lubricants a Tier 1 approach according to the 2006 IPCC Guidelines, vol. 3, chap. 5.2 (IPCC 2006) is applied based on the following formulas:

$$CO_{2,\ Emissions} = AD \bullet EF_{lubricant,\ CO2}$$

$$EF_{lubricant,\ CO2} = NCV_{lubricant} \bullet CC_{lubricant} \bullet ODU_{lubricant} \bullet 44/12$$

Where AD is the activity data, NCV the net calorific value, CC the carbon content and ODU the fraction of lubricants oxidized during use.

Emission Factors

The emission factor of CO_2 from lubricant use in Switzerland is based on default values documented in 2006 IPCC Guidelines (vol. 2, chap.1 and vol. 3, chap. 5.2 for IPCC Default ODU factor of 0.2) and EMIS 2015/2D1 Lubricant use (see Table 4-30).

Table 4-30 CO_2 emission factor of 2D1 Lubricant use and 2D2 Paraffin wax use for 2013 in kg/t (EMIS 2015/2D1 Lubricant use and EMIS 2015/2D2 Paraffin wax use).

	Unit	CO_2
2D1 Lubricant use	kg/t	590
2D2 Paraffin wax use	kg/t	590

Activity Data

The annual amount of lubricant in Switzerland is derived from the Swiss petroleum association (EV 2014) as documented in EMIS 2015/2D1 Lubricant use (see Table 4-31).

Table 4-31 Use of lubricants in Switzerland for the period 1990-2013 in Gg (EMIS 2015/2D1 Lubricant use and EMIS 2015/2D2 Paraffin wax use).

	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
2D1 Lubricant use	Gg	80	75	71	68	63	61	62	65	59	62
2D2 Paraffin wax use	Gg	11	12	11	11	11	10	10	11	11	12

	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
2D1 Lubricant use	Gg	63	56	55	72	74	72	68	71	66	52
2D2 Paraffin wax use	Gg	12	11	11	11	12	10	11	9	9	6

	Unit	2010	2011	2012	2013
2D1 Lubricant use	Gg	55	54	51	53
2D2 Paraffin wax use	Gg	5	5	3	5

4.5.2.2 Paraffin wax use (2D2)

The source category 2D2 Paraffin wax use includes such products as petroleum jelly, paraffin waxes and other waxes, including mixtures of saturated hydrocarbons, solid at ambient temperature. Paraffin waxes are separated from crude oil during the production of light (distillate) lubricating oils.

Emissions from the use of waxes derive primarily when the waxes or derivatives of paraffins are combusted during use (e.g. candles).

Methodology

For the calculation of CO_2 emissions from oxidation of paraffin wax a Tier 1 approach according to the 2006 IPCC Guidelines, vol. 3, chap. 5.3 (IPCC 2006) is applied based on following formulas:

$$CO_{2,\ Emissions} = AD \bullet EF_{wax}$$

$$EF_{wax,\ CO2} = NCV_{wax} \bullet CC_{wax} \bullet ODU_{wax} \bullet 44/12$$

Where AD is the activity data, NCV the net calorific value, CC the carbon content of paraffin wax and ODU the fraction of oxidized paraffin wax.

Emission Factors

The emission factor of CO_2 from paraffin wax use in Switzerland is based on default values documented in the 2006 IPCC Guidelines (vol. 2, chap.1 and vol. 3, chap. 5.3 for IPCC Default ODU factor of 0.2) and EMIS 2015/2D2 Paraffin wax use (see Table 4-30).

Activity Data

The annual amount of paraffin wax use in Switzerland is derived from the Swiss petroleum association as documented in EMIS 2015/2D2 Paraffin wax use (for activity data see Table 4-31).

4.5.2.3 Other (2D3)

Solvent use (2D3a)

In the following sections the NMVOC emissions from coating applications (2D3d NFR), degreasing (2D3e NFR), dry cleaning (2D3f NFR) as well as production and processing of chemical products (2D3g NFR) are reported. Due to the obligations of the Ordinance on Air Pollution Control (Swiss Confederation 1985) and Ordinance on the Incentive Tax on Volatile Organic Compounds (Swiss Confederation 1997) several industrial plants use facilities and equipment to reduce NMVOC in exhaust gases and room ventilation output. Often this implies the feeding of air with high NMVOC content into the burning chamber of boilers or other facilities to incinerate NMVOC. This post-combustion of NMVOC leads to additional direct CO_2 emissions. They are estimated based on industry data and expert estimates (Carbotech 2014a).

Coating applications (2D3d NFR)

Methodology

For the determination of NMVOC emissions from coating applications a country-specific method based on the consumption of paints, lacquers, thinners etc. and their solvent content is used. Switzerland's Informative Inventory Report 2015 contains a description of the country-specific methods used for estimating the NMVOC emissions from 2D3d NFR Coating applications (FOEN 2015f).

Emission Factors

Emission factors for NMVOC emissions are based on data from the Swiss association for coating and paint applications (VSLF) and from relevant retailers, documented in the EMIS database (EMIS 2015/2D3a), see Table 4-32.

For paint application in construction, which is the most important NMVOC emission source in 2D3a Solvent use, the emission factor amounts to 56 kg NMVOC per ton of paint in 2013 (EMIS 2015/2D3a Farben-Anwendung Bau).

Table 4-32 NMVOC emission factors of coating applications, degreasing, dry cleaning, chemical products, manufacture and processing in 2D3a Solvent use for 2013 (EMIS 2015/2D3a).

2D3a Solvent use	**Unit**	**NMVOC**
Coating applications (2D3d NFR)		
Paint application, construction	kg/t paint	56
Paint application, households	kg/t paint	73
Paint application, industrial & non-industrial	kg/t paint	350
Paint application, wood	kg/t paint	295
Paint application, car repair	kg/t paint	400
Degreasing (2D3e NFR)		
Cleaning of electronic components	kg/t solvent	577
Degreasing of metal	kg/t solvent	550
Dry cleaning (2D3f NFR)	kg/t solvent	500
Chemical products, manufacture and processing (2D3g NFR)		
Fine chemicals production	t/production index	3.6
Glue production	kg/t glue	0.8
Handling and storing of solvents	t/production index	2.0
Ink production	kg/t ink	8.5
Paint production	kg/t paint	3.5
Pharmaceutical production	kg/t pharmaceutical	7.8
Polyester processing	kg/t polyester	50
Polystyrene processing	kg/t polystyrene	17
Polyurethane processing	kg/t polyruethane	3.9
PVC processing	kg/t PVC	4.0
Rubber processing	kg/tyres	0.14
Tanning of leather	kg/employee	680

Activity Data

Activity data correspond to the annual consumption of paints. Data on paint consumption are taken from the Swiss association for coating and paint applications (VSLF) and from relevant retailers, documented in the EMIS database (EMIS 2015/2D3a) see Table 4-33.

For paint application in construction, which is the most important NMVOC source in source category 2D3a Solvent use, the activity data equal the consumption of 61'000 t paint in 2013 (EMIS 2015/2D3a Farben-Anwendung Bau).

Table 4-33 Activity data of coating applications, degreasing, dry cleaning and chemical products, manufacture and processing in Switzerland for the period 1990-2013 (EMIS 2015/2D3a).

2D3a Solvent use	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Coating applications (2D3d NFR)											
Paint application, construction	t	122'000	110'750	99'500	88'250	77'000	65'750	54'500	43'250	32'000	32'333
Paint application, households	t	12'000	12'125	12'250	12'375	12'500	12'625	12'750	12'875	13'000	13'000
Paint application, industrial & non-industrial	t	20'100	20'338	20'575	20'813	21'050	21'288	21'525	21'763	22'000	21'467
Paint application, wood	t	6'000	6'063	6'125	6'188	6'250	6'313	6'375	6'438	6'500	6'500
Paint application, car repair	t	2'700	2'600	2'500	2'400	2'300	2'200	2'133	2'067	2'000	2'000
Degreasing (2D3e NFR)											
Cleaning of electronic components	t	900	831	763	694	625	556	488	419	350	350
Degreasing of metal	t	15'500	14'404	13'308	12'211	11'115	10'019	8'923	7'826	6'730	6'333
Dry cleaning (2D3f NFR)	t	1'300	1'242	1'184	1'127	1'069	1'011	953	895	837	780
Chemical products, manufacture and processing (2D3g NFR)											
Fine chemicals production	prod. index	70	71	74	79	91	100	110	126	136	152
Glue production	t	19'000	21'536	24'073	26'609	29'145	31'682	34'218	36'755	39'291	41'827
Handling and storing of solvents	prod. index	70	71	74	79	91	100	110	126	136	152
Ink production	t	20'200	19'675	19'150	18'625	18'100	17'575	17'050	16'525	16'000	17'000
Paint production	t	138'000	131'500	125'000	123'833	122'667	121'500	120'333	119'167	118'000	117'667
Pharmaceutical production	t	16'100	17'075	18'050	19'025	20'000	20'975	21'950	22'925	23'900	22'067
Polyester processing	t	10'800	7'100	7'086	7'071	7'057	7'043	7'029	7'014	7'000	6'733
Polystyrene processing	t	19'600	18'500	18'300	18'600	20'500	19'100	18'000	19'300	18'200	21'900
Polyurethane processing	t	17'300	16'300	20'000	24'500	28'800	34'500	41'900	43'100	40'900	46'800
Production of adhesive tape	t	1'520	1'216	912	608	304	0	0	0	0	0
PVC processing	t	94'000	94'000	94'000	94'000	94'000	94'000	94'000	94'000	94'000	86'000
Rubber processing	tyres	120'000	119'875	119'750	119'625	119'500	119'375	119'250	119'125	119'000	111'333
Tanning of leather	employees	110	110	109	109	109	108	108	107	107	105

2D3a Solvent use	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Coating applications (2D3d NFR)											
Paint application, construction	t	32'667	33'000	35'500	38'000	40'500	42'000	43'500	45'000	48'000	51'000
Paint application, households	t	13'000	13'000	15'333	17'667	20'000	20'000	20'000	20'000	22'667	25'333
Paint application, industrial & non-industrial	t	20'933	20'400	16'467	12'533	8'600	8'767	8'933	9'100	8'833	8'567
Paint application, wood	t	6'500	6'500	6'833	7'167	7'500	7'667	7'833	8'000	8'667	9'333
Paint application, car repair	t	2'000	2'000	1'967	1'933	1'900	1'867	1'833	1'800	1'767	1'733
Degreasing (2D3e NFR)											
Cleaning of electronic components	t	350	350	460	570	680	643	607	570	566	562
Degreasing of metal	t	5'937	5'540	4'570	3'600	2'630	2'557	2'483	2'410	2'382	2'355
Dry cleaning (2D3f NFR)	t	722	664	606	548	491	433	375	317	259	201
Chemical products, manufacture and processing (2D3g NFR)											
Fine chemicals production	prod. index	163	172	182	197	206	224	246	283	280	295
Glue production	t	44'364	46'900	50'433	53'967	57'500	59'767	62'033	64'300	63'969	63'638
Handling and storing of solvents	prod. index	163	172	182	197	206	224	246	283	280	295
Ink production	t	18'000	19'000	18'467	17'933	17'400	17'767	18'133	18'500	18'667	18'833
Paint production	t	117'333	117'000	118'333	119'667	121'000	122'333	123'667	125'000	125'333	125'667
Pharmaceutical production	t	20'233	18'400	24'600	25'900	26'900	27'600	28'300	29'000	29'250	29'500
Polyester processing	t	6'467	6'200	6'300	6'400	6'500	6'867	7'233	7'600	6'200	4'800
Polystyrene processing	t	18'800	20'300	19'300	21'000	22'400	23'500	25'800	26'000	28'575	31'150
Polyurethane processing	t	44'500	50'600	50'300	47'900	53'700	53'900	59'200	69'600	67'400	51'700
Production of adhesive tape	t	0	0	0	0	0	0	0	0	0	0
PVC processing	t	78'000	70'000	62'600	60'100	67'200	64'000	68'800	78'400	72'900	62'300
Rubber processing	tyres	103'667	96'000	94'000	90'000	75'000	67'000	70'000	70'000	72'500	75'000
Tanning of leather	employees	102	100	98	95	93	88	88	87	87	87

2D3a Solvent use	Unit	2010	2011	2012	2013
Coating applications (2D3d NFR)					
Paint application, construction	t	54'000	56'333	58'667	61'000
Paint application, households	t	28'000	28'200	28'400	28'600
Paint application, industrial & non-industrial	t	8'300	8'170	8'040	7'910
Paint application, wood	t	10'000	10'000	10'000	10'000
Paint application, car repair	t	1'700	1'680	1'660	1'640
Degreasing (2D3e NFR)					
Cleaning of electronic components	t	558	555	551	547
Degreasing of metal	t	2'327	2'299	2'272	2'244
Dry cleaning (2D3f NFR)	t	144	86	28	28
Chemical products, manufacture and processing (2D3g NFR)					
Fine chemicals production	prod. index	314	299	303	307
Glue production	t	63'308	62'977	62'646	62'315
Handling and storing of solvents	prod. index	314	299	303	307
Ink production	t	19'000	21'433	23'867	26'300
Paint production	t	126'000	125'400	124'800	124'200
Pharmaceutical production	t	29'750	30'000	29'978	29'955
Polyester processing	t	3'400	3'500	3'700	3'700
Polystyrene processing	t	33'725	36'300	31'000	31'500
Polyurethane processing	t	54'200	40'300	40'200	38'200
Production of adhesive tape	t	0	0	0	0
PVC processing	t	51'700	55'200	39'700	38'488
Rubber processing	tyres	77'500	80'000	80'000	81'000
Tanning of leather	employees	87	87	86	85

Degreasing and dry cleaning (2D3e NFR, 2D3f NFR)

Methodology

For the determination of NMVOC emissions from degreasing and dry cleaning a country-specific method based on the consumption of solvents is used. Switzerland's Informative

Inventory Report 2015 contains a description of the country-specific methods used for estimating the NMVOC emissions from 2D3e NFR, 2D3f NFR Degreasing and dry cleaning (FOEN 2015f).

Emission Factors

Emission factors for NMVOC emissions are based on data from Swiss industry and expert estimates, documented in the EMIS database (EMIS 2015/2D3a).

For degreasing of metal, which is the most important NMVOC source in source category 2D3a Degreasing and dry cleaning, the emission factor amounts to 550 kg NMVOC per ton of solvent in 2013 (EMIS 2015/2D3a Metallreinigung). For emission factors see Table 4-32.

Activity Data

Activity data correspond to the annual consumption of solvents for degreasing and dry cleaning. Data are based on industry data and expert estimates, documented in the EMIS database (EMIS 2015/2D3a).

For degreasing of metal, which is the most important NMVOC source in source category 2D3a Degreasing and dry cleaning, the activity data equal to 2'244 t solvent in 2013 (EMIS 20154/2D3a Metallreinigung). Further activity data is provided in Table 4-33.

Chemical products, manufacture and processing (2D3g NFR)

Methodology

For determination of NMVOC emissions from chemical products, manufacture and processing a country-specific method is used. The emissions from fine chemical and pharmaceutical production are based on production data and expert estimates. The emissions of handling and storage of solvents are calculated based on the imported quantities. The emissions from manufacturing paint, glues, inks, adhesive tape, rubber and polyurethane as well as the processing of PVC are calculated based on production data. The emissions from processing of polystyrene foam and polyester are calculated based on consumption data. Switzerland's Informative Inventory Report 2015 contains a description of the country-specific methods used for estimating the NMVOC emissions from 2D3g NFR Chemical products, manufacture and processing (FOEN 2015f).

Emission Factors

Emission factors for NMVOC emissions are based on data from Swiss industry, industry associations and expert estimates, documented in the EMIS database (EMIS 2015/2D3a). Emission factors for handling and storage of solvents are estimated according to the solvent vapour pressure.

For fine chemical production, which is the most important NMVOC source in source category 2D3a Chemical products, manufacture and processing, the emission factor amounts to 3.6 ton NMVOC per production index in 2013 (EMIS 2015/2D3a Feinchemikalien-Produktion). For emission factors see Table 4-32.

Activity Data

Activity data correspond to the annual consumption of solvents and is based on data from industry, industry associations and expert estimates, documented in the EMIS database (EMIS 2015/2D3a).

For fine chemical production the activity data equal to a production index of 307 in 2013 (EMIS 2015/2D3a Feinchemikalien-Produktion). For activity data the index of production according to the Swiss Federal Office of Statistics is used. For further activity data see Table 4-33.

Road paving with asphalt (2D3b)

Asphalt road surfaces are composed of compacted aggregate and asphalt binder. From road surfacing operations only NMVOC emissions occur.

Methodology

The NMVOC emissions are determined by a country-specific method as documented in EMIS 2015/2D3b Strassenbelagsarbeiten and calculated by multiplying the annual amount of asphalt products used for road paving by the corresponding emission factor.

Emission Factors

The emission factor for NMVOC emissions from road paving with asphalt is country-specific. It consists of a EF for the NMVOC emissions from the bitumen content of asphalt products which is decreasing since 1990 and a variable EF from prime coatings. The values are based on industry data from 1990, 1998, 2007 and 2010. All other years are interpolated and complemented with expert estimates as documented in EMIS 2015/2D3b Strassenbelags-arbeiten (see Table 4-34).

Table 4-34 Emission factors for 2013 for CO and NMVOC in kg/t asphalt concrete and asphalt sealing sheeting from 2D3b Road paving with asphalt and 2D3c Asphalt roofing, respectively (EMIS 20154/2D3b Strassenbelagsarbeiten and EMIS 2015/2D3c Dachpappenproduktion und Verlegung).

	Unit	CO	NMVOC
2D3b Road paving	kg/t asphalt concrete	NA	0.54
2D3c Asphalt roofing	kg/t asphalt sealing sheeting	122	20

Activity Data

Activity data on annual production of asphalt concrete are provided by the industry association on a yearly basis from 1998 on and for 1990 and 1995 (with expert estimates for the years in between) as documented in EMIS 2015/2D3b Strassenbelagsarbeiten (see Table 4-35).

Table 4-35 Activity data for road paving with asphalt, asphalt roofing and urea use in SCR catalysts for the period 1990-2013 in kt (EMIS 2015/2D3b Strassenbelagsarbeiten, EMIS 2015/2D3c Dachpappenproduktion und Verlegung, EMIS 2015/2D3d Urea (AdBlue) Einsatz Strassenverkehr).

	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
2D3b Road paving with asphalt											
Asphalt concrete	kt	5'500	5'360	5'220	5'080	4'940	4'800	4'763	4'727	4'690	5'070
2D3c Asphalt roofing											
Asphalt sealing sheeting	kt	50	49	48	47	46	45	44	42	41	41
2D3d Urea use in SCR catalysts											
AdBlue	kt	0	0	0	0	0	0	0	0	0	0

	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
2D3b Road paving with asphalt											
Asphalt concrete	kt	5'170	4'860	4'770	4'860	4'840	4'780	5'400	5'100	5'160	5'200
2D3c Asphalt roofing											
Asphalt sealing sheeting	kt	41	41	38	35	32	30	28	26	25	25
2D3d Urea use in SCR catalysts											
AdBlue	kt	0	0	0	0	0	0.3	2.6	5.6	10	14

	Unit	2010	2011	2012	2013
2D3b Road paving with asphalt					
Asphalt concrete	kt	5'250	5'300	4'770	4'770
2D3c Asphalt roofing					
Asphalt sealing sheeting	kt	25	24	24	23
2D3d Urea use in SCR catalysts					
AdBlue	kt	17	19	21	23

Asphalt roofing (2D3c)

This source category comprises emissions from production and use of asphalt roofing materials (saturated felt, roofing and siding shingles, roll roofing and sidings). These products are used in roofing and other building applications. From 2D3c Asphalt roofing only precursors such as CO and NMVOC arise. CO is emitted during the production process of asphalt roofing materials whereas NMVOC emissions are released during the entire production and laying processes (primers included).

Methodology

Emissions of CO and NMVOC from asphalt roofing are calculated by multiplying the annual amounts of asphalt roofing products and primers produced and employed by the corresponding emission factors.

Emission Factors

The emission factors for CO and NMVOC emissions from asphalt roofing processes are country-specific. They are based on measurements, industry data and expert estimates as documented in EMIS 2015/2D3c Dachpappenproduktion und Verlegung (see Table 4-34).

Activity Data

Activity data on asphalt roofing products and primers produced are based on industry and expert estimates as documented in EMIS 2015/2D3c Dachpappen Produktion und Verlegung (see Table 4-35).

Urea use in SCR catalysts of diesel engines (2D3d)

This source category encompasses CO_2 emissions from the use of urea containing AdBlue in diesel engines with SCR-catalysts in road transportation (Euro V/VI).

Methodology

For the first time and in accordance with the new 2006 IPCC guidelines the consumption of Ad Blue is reported in this submission following a methodology suggested in the EMEP/EEA guidebook 2013 (EMEP/EEA 2013; part B, chap. 1.A.3.b.i-iv, page 48). A specific percentage of the fuel consumption of SCR-vehicles in road transportation according to their Euro class is applied for Ad Blue consumption estimates. Emissions are calculated according to following formula:

CO_2 Emissions = EF • FC • Share of SCR vehicles mileage • Specific urea share

“FC” relates to the fuel consumption in [t] of the entire vehicle category. “Share of SCR vehicles mileage” implies the mileage share of SCR-vehicles in the entire vehicle category and “Specific urea share” comprises the percentage of fuel consumption which relates to AdBlue (urea solution) consumption.

Emission Factors

The emission factor for CO_2 emissions from urea use in SCR-catalysts in vehicles is a default value (EMEP/EEA 2013) considering the molecular mass conversion of urea into CO_2 during the reaction with water and the content of 32.5% of the aqueous AdBlue urea solution. The EF amounts to 0.238 t per ton of AdBlue.

Activity Data

Activity data on annual mileage, fuel and AdBlue consumption are provided by INFRAS (INFRAS 2010) on a yearly basis as documented in EMIS 2015/2D3d Urea (AdBlue) Einsatz Strassenverkehr. The activity data equal to 22'707 t AdBlue in 2013 (see Table 4-35).

4.5.3 Uncertainties and Time-Series Consistency

The uncertainty of total CO_2 emissions from the entire source category 2D – Non-energy products from fuels and solvent use is estimated to be 50% (expert estimate).

Consistency: Time series for 2D Non-energy products from fuels and solvent use are all considered consistent.

4.5.4 Source-Specific QA/QC and Verification

The general QA/QC measures are described in section 1.2.3.

4.5.5 Source-Specific Recalculations

2D1 Lubricant use: CO_2 emissions are newly reported in the inventory for the entire time series 1990-2013 according to the 2006 IPCC Guidelines.

2D2 Paraffin wax use: CO_2 emissions are newly reported in the inventory for the entire time series 1990-2013 according to the 2006 IPCC Guidelines.

2D3a Coating applications:

- The AD and NMVOC EF for 2D3a (2D3d NFR) Paint application, construction and 2D3a (2D3d NFR) Paint application, wood have been updated for 2013 resulting in revised interpolated values for 2011 and 2012.
- The two source categories 2D3a (2D3d NFR) Industrial paint application, other and 2D3a (2D3d NFR) Non-industrial paint application, other have been combined in one source category 2D3a (2D3d NFR) Paint application, industrial & non-industrial resulting in small rounding changes in the NMVOC EF values between 2001 and 2012. Due to the updated AD for 2013 also the interpolated AD values for 2011 and 2012 have been revised.

2D3a Chemical products, manufacture and processing (2D3g NFR):

- The AD and NMVOC EF for 2D3a (2D3g NFR) Polyurethane processing have been updated for 2008–2012 and 2012, respectively, resulting in revised interpolated EF values for 2008–2011 as well.
- The AD and NMVOC EF for 2D3a (2D3g NFR) Ink production have been updated for 2013 resulting in revised interpolated values for 2011 and 2012.
- The NMVOC EF for 2D3a (2D3g NFR) Polystyrene processing has been updated for 2012 resulting in revised interpolated EF values for 2008-2011 as well.

2D3c Asphalt roofing: The NMVOC EF for 2D3c Asphalt roofing has been updated for 2013 resulting in revised interpolated EF values for 2011 and 2012.

2D3d Urea use in SCR catalysts of diesel engines: CO_2 emissions are newly reported in the inventory for the entire time series 1990-2013 according to the CRF templates.

4.5.6 Source-Specific Planned Improvements

No source-specific improvements are planned.

4.6 Source Category 2E – Electronics Industry

4.6.1 Source Category Description

Source category 2E Electronics industry comprises HFC, PFC, NF_3 and SF_6 emissions from consumption of the applications listed below in Table 4-36. The definition of the category 2E Electronics industry has been introduced for the second commitment period and replaces the former category 2F7 Semiconductor manufacture (and further electronic industry related activities so far included under 2F9 Other and 2F5 Solvents).

Table 4-36 Specification of source category 2E Electronics industry. Data source: Carbotech (2015).

2E	Source	Specification	Data source
2E1	Integrated Circuit or Semiconductur	Etching and cleaning processes in the production of IC and semiconductors (similar cleaning services for printed wiring boards included in the evaluation)	AD: import statistics, industry data (Carbotech 2015) EF: IPCC default value (IPCC 2006)
2E2	TFT flat panel display	No production of TFT flat panel displays in Switzerland, activities contained in the production of displays for watches	No information obtained (import amount covered under 2E1)
2E3	Photovoltaics	Emissions from photovoltaic manufacturing	AD: import statistics, industry data (Carbotech 2015) EF: IPCC default value (IPCC 2006)
2E4	Heat transfer fluids	No application in Switzerland assumed*	Assumption based on interviews with electronic industry and import companies
2E5	Other	Test activities (for example related to printed wiring boards), research activities	AD: import statistics, industry data (Carbotech 2015) EF: assumption equal to value semiconductors

* Heat transfer fluids subject of research, for example ORC systems. Alternative products available with low GWP as for example Novec 649 and 7000

4.6.2 Methodological Issues

Emission calculations are based on import data from FOEN statistics for etching and cleaning processes of the electronic industry covering different source categories as listed in Table 4-36 (until 2010 import declarations under solvents). Process-specific transformation and emission rates were used. A request within industry was carried out for the inventory 2013 to distribute the substances to the different source categories of electronic industry. In the first commitment period related processes had been evaluated mainly under the former categories 2F7 Semiconductor manufacturing and partly under 2F5 Solvents and 2F9 Other.

Methodology

A Tier 2a approach with process gas-specific parameters was used for emission calculations. IPCC default values for gas-specific transformation rate of different processes and general values for exhaust treatment efficiency were applied.

Imports of electronics industry were included in FOEN statistics under solvents until 2010. For the inventory report 2011 (FOEN 2011) interviews were made with industry to get in-depth information on allocation of imported PFC volumes to different applications and to obtain process-specific information from consumers. It then became obvious that until 2010 most PFC import declared as 2F5 Solvents or 2F6 Other was related to the electronics industry (2E). Since 2011 PFCs import declarations have been improved and information is provided for the source category 2E separately. A request was carried out for the inventory 2013 to determine contributions of different sub-source categories 2E1-2E5 (Table 4-36). As a result the peak of NF_3 imports between 2009 and 2011 was found to be related to photovoltaic manufacture.

Emission Factors

Default emission factors as per 2006 IPCC Guidelines are used for production and waste-air treatment. An exhaust treatment is assumed probable for most applications due to legislation under the Chemical Risk Reduction Ordinance (Swiss Confederation 2005), which limits emissions for industrial applications, such as semiconductor manufacturing, to 5%. For some large users the presence of exhaust treatment was confirmed in a survey.

Activity Data

Activity data are based on FOEN import statistics and industry information.

4.6.3 Uncertainties and Time-Series Consistency

The uncertainty for the emissions from the use of PFC, SF_6 and NF_3 in 2E Electronics industry is estimated at 61% (PFC), 57% (SF_6), 92% (NF_3) based on a Monte Carlo simulation (Carbotech 2015).

Consistency: Time series for 2E Electronics industry are all considered consistent.

4.6.4 Source-Specific QA/QC and Verification

The entire time series are compared between the current and the previous submission (evaluations in previous submission under former source category 2F7 Semiconductor and partly under 2F5 Solvents and 2F9 Other). The general QA/QC measures are described in section 1.2.3

4.6.5 Source-Specific Recalculations

2006 IPCC Guidelines (IPCC 2006) introduces a new categorization for electronic industry, new substances and new model approaches for sub-categories with process gas specific transmission rates.

4.6.6 Source-Specific Planned Improvements

No source-specific improvements are planned.

4.7 Source Category 2F – Product Uses as Substitutes for Ozone Depleting Substances

4.7.1 Source Category Description

Approach 1 Key Category 2F1

HFC emissions from product uses as substitutes for ozone depleting substances; refrigeration and air conditioning (level and trend).

Approach 2 Key Category 2F1

HFC emissions from product uses as substitutes for ozone depleting substances; refrigeration and air conditioning (level and trend).

Source category 2F Product uses as substitutes for ozone depleting substances comprises HFC and PFC emissions from consumption of the applications listed in Table 4-37.

Table 4-37 Specification of source category 2F Product uses as substitutes for ozone depleting substances. Data source: Carbotech (2015).

2F	Source	Specification	Data Source
2F1	Refrigeration and air conditioning	Emissions from refrigeration and air conditioning (inclusive heat pumps and tumble dryers)	AD: Various national statistics (SFSO 2014b) and industry data (Carbotech 2015) EF: Industry data and expert estimates (Carbotech 2015)
2F2	Foam blowing agents	Emissions from foam blowing, incl. polyurethan spray	AD: Industry data and import statistics (Carbotech 2015) EF: Expert estimates (Carbotech 2015)
2F3	Fire protection	Not occurring in Switzerland	-
2F4	Aerosols	Emissions from use as aerosols, incl. metered dose inhalers	AD: import statistics EF: IPCC default value (IPCC 2006)
2F5	Solvents	Emissions from use as solvents	AD: import statistics EF: IPCC default value (IPCC 2006)
2F6	Other applications	Not occurring in Switzerland	-

The following graph shows emissions in source category 2F by sub-sector and by different groups of gases. Refrigeration and air conditioning equipment account by far for the highest emissions with a share of 96% of the total emissions in the source category 2F.

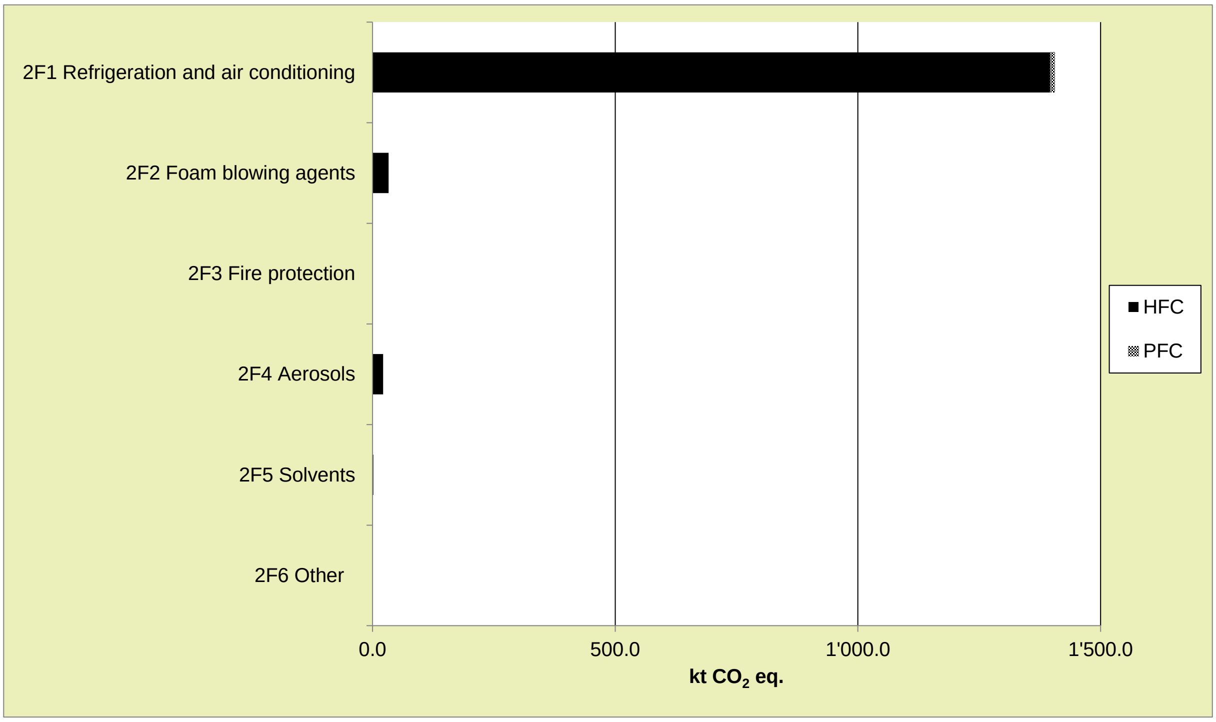


Figure 4-6 Distribution of emissions under source category 2F Product uses as substitutes for ozone depleting substances (2013).

4.7.2 Methodological Issues

The data models used for source category 2F are complex and therefore a comprehensive documentation of all relevant model parameters is not possible within the NIR. Annex A3.2 shows an illustrative example of the model structure and parameters used for calculating emissions from mobile air-conditioning in cars. Where possible, the most important assumptions for the data model are documented (e.g. Table 4-38). Detailed documentation of the individual data models is available from Carbotech (2015) as well as related background documents. This information is FOEN internal due to confidentiality of data, but is open for consultation by reviewers.

4.7.2.1 Refrigeration and Air Conditioning (2F1)

Methodology

The inventory under this sub-source category includes the following types of equipment: domestic refrigeration, commercial and industrial refrigeration, transport refrigeration, stationary air conditioning, mobile air conditioning, heat pumps and tumble dryers. For each of these types of equipment individual emission models are used for calculating actual emissions as per 2006 IPCC Guidelines Tier 2a (emission factor approach). In order to obtain the most reliable data for the calculations, two different approaches are applied to get the stock data needed for the model calculations: 'top down' using import amount of refrigerant and available statistics or estimations on the Swiss market from experts and associations and 'bottom up' through questionnaires sent to companies active in importation, production and service of appliances.

The import data as reported to FOEN were adjusted for imported substances to be used in Liechtenstein. This is to eliminate double counting with the inventory data of Liechtenstein. Under source category 2F1 import data, which is related to commercial and industrial refrigeration equipment, are split between Switzerland and Liechtenstein from the year 2008 onwards. The split factor is based on the proportion of employees in the industrial and service sector (share of import for Liechtenstein < 1%). For other equipment types no scope for double counting with the inventory of Liechtenstein was identified and therefore no adjustment is required.

For the present submission also a number of minor improvements and corrections have been made to the model assumptions on emissions factors and activity data for source category 2F1. Further details can be seen in chapter 10 (Recalculations).

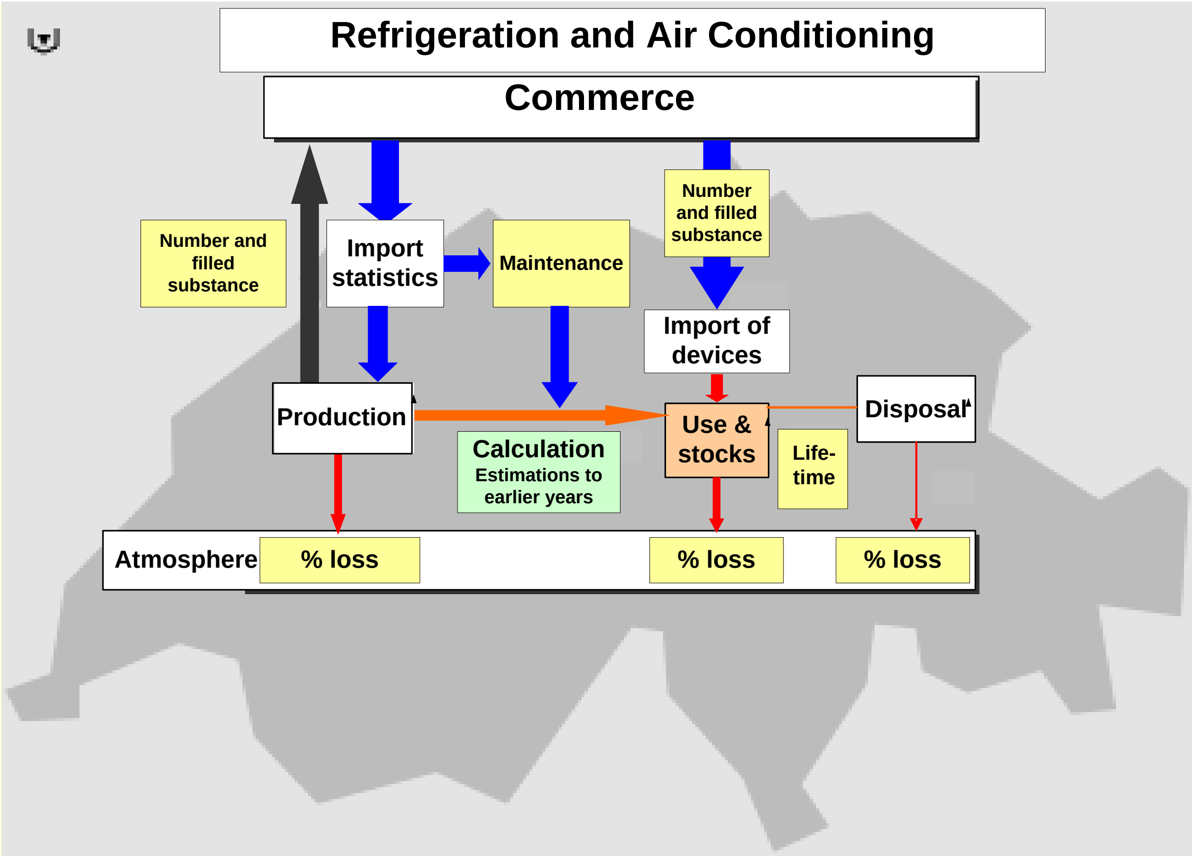


Figure 4-7 Required data for the model to calculate emissions from refrigeration and air conditioning in Switzerland.

Emission Factors

Emission factors for manufacturing, product life and disposal as well as average product lifetime are established on the basis of expert judgement and literature. Direct monitoring of the product life emission factors is only done at the company level (i.e. retailers such as Coop and Migros). The product life factors are used to make the allocation of imported F-gases to new products and maintenance activities.

In 2008 a revised ordinance on chemical risk reduction (Swiss Confederation 2005) was introduced. As part of this revision an obligation for operators handling equipment containing more than 3 kg of HFCs was introduced to provide information to FOEN on the date of operation start, type of equipment, type and amount of refrigerant and date of disposal. Today the statistics on equipment containing more than 3 kg are comprehensive. However, these figures only cover about 50% to 70% of the refrigeration and air conditioning equipment reported under source category 2F1, since there are many types of equipment containing less than 3 kg of HFCs. Furthermore, there is no information available from the statistics regarding the emissions due to operation losses from the registered equipment. This data source provides valuable information to improve the estimates used for modelling emissions under source category 2F. However, it will not allow to directly draw the stock data or emission factors for the National Inventory from this database in the near future.

Table 4-38 displays the detailed model parameters used for the present submission. Changes of model parameters within the period 1990 to 2013 are indicated with values in brackets. The parameters in brackets are applied for the inventory 2013. For product life emission factors of some equipment types a dynamic model is applied which implies that emission losses improve linearly between 1995 and 2013 due to better production technologies and the continuous sensitisation of service technicians. The start/end values are based on expert statements, UBA (2005, 2007) and Schwarz (2001, 2005). The charge at end of life for different applications has been analysed considering the technical minimal charge of equipment and the expected frequency of maintenance (UBA/Ökorecherche 2012). Disposal losses are calculated based on expert assumption on portion of broken equipment (100% loss) and assumptions on disposal losses for professional recovery at site or waste treatment by specialized companies.

Table 4-38 Typical values on lifetime, charge and emission factors used in model calculations 1990 to 2013 for refrigeration and air conditioning equipment. Changes of model parameters within this time period are indicated with the starting year of application in brackets (for example a product life emissions factor of 10% was applied for stationary air conditioning until 2009 and a lower factor of 4% from 2010 onwards). A linear extrapolation was applied for sinking emission factor of commercial and industrial refrigeration and for the sinking charge of mobile air conditioning.

Equipment type	Product life time	Initial charge of new product	Manufacturing emission factor	Product life emission factor	Charge at end of life *)	Export of retiring equipment **)	Disposal loss emission factor ***)
	[a]	[kg]	[% of initial charge]	[% per annum]	[% of initial charge of new product]	[% of retiring equipment]	[% of remaining charge]
Domestic refrigeration	16	0.1	NO	0.5	92	0-5 (2013:3)	19 ****)
Commercial and industrial refrigeration	10	NR	0.5	Sinking from 12 in 1990 to 7 in 2013	78	NA	19
Transport refrigeration: trucks	10	1.8-7.8	1.5	15	86	90	28
Transport refrigeration: wagons	16	NR	NO	10	100	NA	28
Stationary air conditioning: direct cooling systems	15	NR	3	10 (2010: 4)	85-90 (2013: 89)	NA	28
Stationary air conditioning: indirect cooling systems	15	NR	1	6 (2010: 4)	85-90 (2013: 86)	NA	19
Stationary air conditioning: heat pumps	15	4.7-7.5 (2000: 2.8-4.5)	3	2	86	NA	20
Stationary air conditioning: tumble dryers	15	0.4	0.5	2	74	NA	19
Mobile air conditioning: cars	15	Sinking from 0.84 1990 to 0.55 in 2013	NO	8.5	58	31-72 (2013: 45)	50
Mobile air conditioning: truck cabins	12	8.5	NO	10 (2011: 8.35)	69	90	50
Mobile air conditioning: buses	12	7.5	NO	20 (2011: 15)	100	50	50
Mobile air conditioning: trains	16	20	NO	5.5	100	NA	20

*) takes into account refill of losses during product life where applicable.

**) allocation of disposal losses to export country

***) Disposal losses of HFC and PFC occur from 2000 onwards (introduction of HFCs and PFCs starting 1991 and 10 to 16 years lifetime of equipment). Disposal losses include share of total refrigerant loss. The value of 50% for mobile air conditioning is based on UBA 2005 and expert assumptions on share of total refrigerant loss, e.g. due to road accident.

****) takes into account R134a content in foams, based on information from the recycling organisation SENS.

NR = not relevant as only aggregate data is used

NO = Not occurring (only import of charged units)

NA = Not available

Activity Data

Activity data are taken from industry information and national statistics such as for admission of new cars and trucks. Stock data is modelled dynamically. Due to the large number of sub-models used for modelling the total emissions for sub-source category 2F1, no table on time series of activity data is provided here, despite 2F1 being a key category. For illustration, Annex A3.2 shows the detailed calculation model for car air conditioning including the time series for the activity data for this particular sub-model. Mobile air conditioning accounts for approx. 30% of the total emissions (CO_2 eq) of sub-source category 2F1 Refrigeration and air conditioning in the inventory 2014.

For the inventory report 2012 (FOEN 2012) a cross check has been performed for results from model calculation and FOEN statistics on disposal and recycling of HFCs. This has indicated a significant gap. Some of the gap is explained by the onsite reuse and recycling of refrigerants, which is not reflected by the FOEN statistics and with other factors as for example the not accounted export of refrigeration equipment (only export of vehicles with air-conditioning considered). Export rates were considered for further applications in the present submission (refrigerants in mobile air conditioning and transport refrigeration).

To avoid double counting with the inventory data of Liechtenstein, the activity data for the equipment type commercial and industrial refrigeration from the year 2008 onward are reduced by 0.9%, based on the share of imports of substances to be used in Liechtenstein. The reduction factor is based on the proportion of employees in the industrial and service sector in these two countries. For other equipment types no scope for double counting with the inventory of Liechtenstein was identified and therefore no correction factor is applied.

4.7.2.2 Foam Blowing Agents (2F2)

Methodology

In Switzerland no production of open cell foam based on HFCs is reported by the industry. Therefore only closed cell PU and XPS foams, PU spray applications and further closed cell applications as sandwich elements are relevant under this source category.

The emission model (Tier 2a) for foam blowing has been developed ‘top down’ based on import statistics for products, industry information and expert assumptions for market volumes and emission factors. Emissions from further not specified applications – so far assumed to be sandwich elements - have been calculated (Tier 1a) as residual balance between FOEN import statistics and consumption in PU spray, PU and XPS foams.

Emission Factors

For emission factors and lifetime of XPS and PU foam, expert estimates and general default values according to IPCC are used (IPCC 2006: Volume 3, p. 7.37). For PU spray, expert estimates and specific default values according to IPCC (2006, Volume 3, p. 7.37) are used. Unknown applications are evaluated following the Gamlen model recommended in the 2006 IPCC Guidelines (IPCC 2006). First-year losses are allocated to the country of production.

Table 4-39 Typical values on lifetime, charge and emission factors used in model calculations for foam blowing

	Product lifetime	**Charge of new product**	**Manufacturing emission factor**	**Product life emission factor**	**Charge at end of life**
	years	% of product weight	% of initial charge	% per annum	% charge of new product
PU foam	50	4.5	NR	NR	Calculated charge minus emissions over lifetime (so far not relevant, products still in use)
XPS foam HFC-134a XPS foam HFC-152a	50	6.5	NR	NR / 0.7** 100 / 0**	
PU spray all HFC	50	13.6 / 0 *	<1%	95 / 2.5 **	
Unknown use: HFC 134a, HFC 227ea, HFC 365 mfc HFC 152a	20	NR	10 100	10 / 4.5 ** 100 / 0 **	

* Data for start of HFC use 1995 / since 2009

** Data for 1st year / following years (HFC-152a all emissions allocated to production)

NR Not relevant (PU foam: no substances according to this protocol have been used; XPS foam: emissions occur outside Switzerland; unknown use: calculations are based on the remaining propellant import amount).

Activity Data

HFCs have been used until 2008 in the Swiss production of PU spray. The export rate of PU spray from Swiss production is about 96.5% of total production volume. About one third of PU spray sold in Switzerland originates from local production, the rest is import. For PU rigid foams no HFCs are used as foam blowing agent (only Pentane and CO_2). There has been no production of XPS in Switzerland with HFCs. XPS foams were 100% imported until 2010. In 2011 a new production facility was started which, however, does not use HFCs. The HFC import not related to the main applications above has been allocated to further unknown applications (possible use in the production of sandwich elements mentioned by an import company of foam blowing agents has not been confirmed).

Detailed activity data for this sub-source category are available at FOEN, but not reported due to confidentiality.

4.7.2.3 Fire Protection (2F3)

No emissions occurring in this sector within Switzerland. The application of HFCs, PFCs and SF_6 in fire extinguishers is prohibited by law.

4.7.2.4 Aerosols (2F4)

Methodology

The Tier 2a emission model for Aerosol / MDI is based on a 'top-down' approach using import statistics for HFCs.

Emission Factors

A manufacturing emission factor of 1% is applied. For product life emission factor the model assumes that 50% of the remaining substance is emitted in the first year and 50% in the second year respectively, which is in line with 2006 IPCC Guidelines. To account for variations in imports and stocks, the average figure from imports for the actual year (t) and for the past year (t 1) is reported. This emission model can lead to implied product life emission factors of > 100% in case of decreasing imports.

Activity Data

In most aerosol applications, HFC has been replaced already in the past years. According to the information of companies filling aerosol bottles for use in households, e.g. cosmetics, cloth care and paint, no HFC is being used. For special technical applications - especially metered dose inhalers (MDI) - HFC is still in use. Compared to the total amount of aerosol applied, the HFC use for MDI is considered to be irrelevant.

Activity data are based on import statistics. The export and import of filled products is unknown and assumed to be in a similar range. Detailed activity data for this sub-source category are available at FOEN but not reported due to confidentiality.

4.7.2.5 Solvents (2F5)

Methodology

HFCs and PFCs are used as solvents. Emissions are calculated according to Tier 1a method according to the 2006 IPCC Guidelines on basis of a ‘top-down’ approach using import statistics and industry information on allocation of the imported HFC and PFC amounts to different applications.

The import data as reported to FOEN were adjusted for imported substances to be used in Liechtenstein to eliminate double counting. Under source category 2F5 import data from the year 2008 onwards are split between Switzerland and Liechtenstein. The split factor is based on the proportion of inhabitants.

Emission Factors

An emission factor of 50% in the first and in the second year, respectively, is applied in line with the 2006 IPCC Guidelines.

Activity Data

Activity data are based on import statistics. Detailed activity data for this source category are available at FOEN but not reported due to confidentiality. Since the inventory report of the year 2011 (FOEN 2011) interviews were made with industry to get in-depth information on allocation of imported HFCs and PFCs volumes to different applications. These interviews revealed that most imported PFCs declared as Solvents (2F5) or Other (2F9) before 2011 are actually related to the electronics industry. Therefore, the model for allocation of imported PFC volumes was adjusted accordingly. Since 2011 imports for semiconductors manufacturing and further etching processes of electronics industry are registered as separate category in FOEN import statistics.

To avoid double counting with the inventory data of Liechtenstein, the import data reported to FOEN which is assigned to source category 2F5 in the inventory of Switzerland is adjusted by 0.5%. The adjustment factor is based on the proportion of inhabitants in these two countries.

4.7.2.6 Other Applications (2F6)

There are no further applications of substitutes for ozone depleting substances in Switzerland.

4.7.3 Uncertainties and Time-Series Consistency

For refrigeration equipment, air-conditioning equipment as well as for foam blowing, a Monte Carlo analysis according to IPCC Good Practice Guidance for the evaluation of uncertainties of model calculations according to Tier 1 and 2 has been carried out. The Monte Carlo Analysis was performed on the inventory data of the current GHG inventory (submission 2015). For the purpose of the Monte Carlo Analysis, the uncertainty of all relevant parameters (e.g. initial appliance charge, product life emission factor, import and export volumes, etc.) used in the emission models for the applications as per Table 4-40 below has been characterised using the following statistical distributions:

- Triangular distribution (defined by the three parameters minimum, maximum and most likely value)
- Uniform distribution (same probability for the whole spectrum)
- Normal or lognormal distribution

The analysis was carried out with 10’000 cycles. Some details on the distributions of parameters used (i.e. type of distribution, minimum, maximum, most likely value) are documented in the report Carbotech (2015).

For the submission of 12 April 2006 the uncertainty for the import statistic data had been estimated for the first time. Discussions with the persons responsible for data collection in the years 1997–2013 led to the estimations given in Table 4-40.

Table 4-40 Estimated uncertainty for the data of the imported substances.

Year	Minimal	Maximal	Remarks
Up to 1999	-10%	30%	Assumed that the data is not complete
2000 – 2003	-10%	15%	Data can be incomplete or possible double declaration
2004 – 2013	-10%	10%	Data can be incomplete or possible double declaration

The following Table 4-41summarises the results for the application-specific emission models. The “value 2013” represents the reported emissions in kt CO_2 equivalent for the specific application for the year 2013. The average, median, uncertainty, minimum and maximum values are output values of the Monte Carlo Analysis. The uncertainty of the resulting total emissions from the source category 2F Product uses as substitutes for ODS is about 9%. Higher values result for the contributions of single applications.

Uncertainties of more than 20% have been calculated for the following applications:

- Stationary air conditioning
- Domestic refrigeration
- Foam blowing
- Aerosols
- Solvents

Uncertainties of 15% to 20% have been calculated for the following applications:

- Mobile air conditioning
- Commercial and industrial refrigeration
- Transport refrigeration

For the model calculation of domestic refrigeration no uncertainty value is given due to a very asymmetric distribution. Calculation of stocks is not reported in detail here because the uncertainties for stock and new filled refrigerant related to the split of refrigerant on different applications is of small importance for the overall emissions (different applications show similar characteristics for the building of stocks and related emissions). Detailed data are available from Carbotech (2015). For stocks maximum uncertainties of 30% result for HFC-32 in commercial and industrial refrigeration.

Relevant parameters for the building of stock in PU-foam are the PU-foam import and export rate of past years and the PU-Spray first year emission factor. The data base for PU-Sprays has been significantly improved with effect from the 2007 submission (FOEN 2007). This is attributed to improved models which have been elaborated by the main producer and its blowing agent import firm. However, the following three factors lead to a small amount remaining in the stock with a relative high uncertainty: high import and export rate of PU-Spray, lacking information on import of PU-Spray and on propellant used in import products and high emission factor of the first year.

Table 4-41 Summary of results for model parameter “emissions” from Monte Carlo Analysis for 2013 data on selected emission sources.

Application	Model para-meter	Value 2013 kt CO_2 eq.	Average kt CO_2 eq.	Median kt CO_2 eq.	min. kt CO_2 eq.	max. kt CO_2 eq.	Uncer-tainty %
2F1 Refrigeration and air conditioning	Emissions in kt CO_2 eq.	1'405	1'419	1'414	957	2'002	17
- Commercial / Industrial refrigeration		765	762	759	580	1'031	15
- Mobile air conditioning		419	418	418	276	570	16
- Stationary air conditioning		184	200	200	79	329	27
- Transport refrigeration		28.4	31.0	30.9	22.9	42.0	18
- Domestic refrigeration		8.2	7.8	6.0	0.2	31.0	*)
2F2 Foam blowing agents		32.9	36.8	36.6	23.7	62.0	15
2F4 Aerosols		22.0	22.0	21.9	9.0	38.0	41
2F5 Solvents		1.9	1.9	1.9	0.4	3.0	55
Total 2F Product use as substitutes for ODS		1'462	1'480	1'478	1'261	1'812	9

*) very asymmetric distribution, therefore standard deviation not indicated.

Consistency: Time series for 2F are all considered consistent.

4.7.4 Source-Specific QA/QC and Verification

The entire time series are compared between the current and the previous submission.

Recalculations were identified and explained. Detailed controls of all modelling results produced by Carbotech (2015) have been carried out by FOEN specialists.

The assumptions of decreasing emissions factors for the different equipment types under sub-source category 2F1 Refrigeration and air conditioning have been cross-checked with the inventories of Austria and Germany and have been found to be in line with the assumptions made for these inventories.

The emission factor of category 2F used in the Swiss Inventory was compared to the corresponding emission factors of other countries (UNFCCC http://unfccc.int/di/FlexibleQueries.do) and to the IPCC default value if available (INFRAS 2012). Concerning ODS substitutes the following sources of emissions are deemed most relevant: HFC-125, HFC-134a and HFC-143a from stationary and commercial refrigeration as well as mobile air conditioning. The product life factor is relevant, since there is no production of halocarbons in Switzerland. For all these sources Switzerland's emission factors lie in the midfield of the range of other countries except for the life factor in mobile air conditioning. However, when compared to neighbouring countries such as Germany, very similar values are used. The Swiss product life factors are often lower than the average for the following reasons. First, since 2005 the ordinance on Chemical Risk Reduction (Swiss Confederation 2005) is in place that ensures the proper handling and disposal of halocarbons and SF_6. Second, the decommissioning sector is well-organized by the SENS foundation and recycling is taxed in advance. Third, servicing staff is well-trained to proper handling and disposal of respective appliances.

The FOEN supports a monitoring campaign at the high-altitude research station Jungfraujoch, where various greenhouse gases are measured continuously. The location of the research station normally provides for analysis of tropospheric background concentrations. However, under special meteorological conditions, an estimate of Swiss emissions can be derived from the measurements. For HFC-134a, HFC-125, HFC-152a HFC-143a, HFC-336mfc and HFC-32, a comparison of the inventory data with the inferred emissions is presented in Annex A5.1.

4.7.5 Source-Specific Recalculations

A new categorization was introduced with the 2006 IPCC Guidelines for fluorinated substances. The former evaluation under 2F consumption of HFC, PFC and SF_6 was split into the new categories 2F Product uses as substitutes for ODS, 2E Electronics industry, 2G Other product manufacture and use. With the application of the 2006 IPCC Guidelines new GWP values were applied and additional substances included in evaluations (HFC-365mfc and HFC-254fa relevant for ODS substitutes). Further but less relevant changes result from optimizations of model calculations.

Source-specific recalculations for the time series 1990 to 2012 are summarized in Table 4-42 for the remaining applications in the new category 2F Product uses as substitutes for ODS. The different improvements carried out in the present inventory are related to the sub-source categories with the highest emissions (in 2F1).

A direct comparison of results in category 2F with results from the past submission is not possible due to the new categorization. The recalculation of the emissions 2012 lead to 19% higher emissions in the former category 2F consumption of HFC, PFC and SF_6 than reported in the previous submission (278 kt CO_2 in 2012). A difference of about 5% results from model optimization and of about 14% from changes in applied GWP values and new substances.

Table 4-42 Summary of recalculations in source category 2F.

NFR code	Sector/ Process	AD/EF	Year	Gas	Specification
2F	Product uses as substitutes for ODS	-	1990-2012	All F-Gas	New GWP values (mostly higher)
2F1	Refrigeration and air conditioning	AD	2003-2012	HFC-134a	Mobile air conditioning, lower charge equipment. Indirect influence on calculation of industrial/commercial refrigeration, split of imports of in bulk on applications.
2F1	Refrigeration and air conditioning	AD	2002-2013	HFC-134a, HFC-125, HFC-32	Stationary air conditioning, new application included in model (tumble dryers). Indirect influence on calculation of industrial/commercial refrigeration, split of imports of in bulk on applications.
2F1	Refrigeration and air conditioning	AD	1991-2012	HFC-134a, HFC-143a HFC-125, HFC-32, C_3F_8	Harmonization of model calculations (for example elimination of averages over two years for emission estimates from stock, only stock of specific year considered). The harmonization leads to significant changes of calculations in the early phase of HFC and PFC application in commercial and industrial refrigeration and mobile air coinditioning (1991 to 1996)
2F1	Refrigeration and air conditioning	AD	2004-2012	HFC-245fa, HFC-235fa, CF_4	New model calcualations for so far neglected small import amounts of refrigerants (assumed use commercial and industrial refrigeration)
2F2	Foam blowing agents	EF	2002-2012	HFC-134a, HFC-152a, HFC-227, HFC-365mfc	New model approach for unknown application (IPCC 2006 recommendation Gamlen model, changes of lifetime and losses, disposal AD so far not relevant).
2F5	Solvents	AD		HFC-134a, HFC-245fa, C_3F_8, C_4F_8, C_4F_{10}, C_6F_{14}	Shift of substances to other applications. HFC-134a and HFC-245fa to 2F4 Aerosols (IPCC 2006: aerosol solvents included unter arosols), shift of PFCs to 2E Electronics industry and 2G2 Other PFC and SF_6 use

4.7.6 Source-Specific Planned Improvements

Gradual improvement of the data quality in co-operation with industry is ongoing. As in the past years, methodologies and emission models will be updated during the yearly process of F-gas inquiry. The focus will be on improvements of HFC-emission calculations from refrigeration and air-conditioning equipment.

4.8 Source Category 2G – Other Product Manufacture and Use

4.8.1 Source Category Description

Approach 1 Key category 2G

SF_6 emissions from Other product manufacture and use (level).

Approach 1 Key category 2G

HFC emissions from Other product manufacture and use (trend).

Approach 2 Key category 2G

N_2O emissions from Other product manufacture and use (trend).

Source category 2G Other product manufacture and use comprises SF_6 and PFC emissions from electrical equipment and other product use, as well as N_2O emissions from the application in households and hospitals. Moreover, it comprises CO_2 emissions resulting from post-combustion of NMVOC in exhaust gases and additional emissions of CO_2, NOx, CO and SO_2 from the use of fireworks. HFC emissions not accounted in other source categories are also included here.

Table 4-43 Specification of source category 2G Other product manufacture and use. EMIS 2015/… refers to the internal documentation of the emission database and contains further references regarding specific AD and/or EF.

2G	Source	Specification	Data Source
2G1	Electrical equipment	Emissions of SF_6 from use in electrical equipment	AD: industry data EF: industry data
2G2	SF_6 and PFCs from other product use	Emissions of SF_6 and PFC not accounted in other source categories (i.e. for particle accelerators, soundproof windows, leakage detection, research and laboratory use)	AD: import statistics and Industry data (Carbotech 2015) EF: industry data and estimates (Carbotech 2015)
2G3	N_2O from product uses	Emissions of N_2O from the use of N_2O in hospitals; Emissions of N_2O from the use of aerosol cans	AD, EF: EMIS 2015/2G3a Lachgasanwendung Spitäler, EMIS 2015/2G3a Lachgasanwendung Haushalt
2G4	Other	Emissions of CO_2 and NMVOC from use of spray cans in industry and households; domestic solvent use; print industry; application of glues and adhesives; use of concrete additives; removal of paint and lacquer; car underbody sealant; de-icing of airplanes; tanning of leather; impregnating of glass and mineral wool; use of cooling and other lubricants; extraction of oils and fats; use of pesticides; use of pharmaceutical products in households; house cleaning industry/craft/services; hairdressers; scientific laboratories; textile production; paper and paper board production; clothing production; cosmetic institutions; production and use of tobacco products; vehicles dewaxing; wood preservation; medical practitioners; other health care institutions; not attributable solvent emissions; Emissions of CO_2 from use of fireworks; Emissions of HFC not accounted in other source categories	AD, EF: EMIS 2015/2G4; AD for HFC: import statistics and industry data, EF for HFC: industry data and estimates

4.8.2 Methodological Issues

4.8.2.1 Electrical equipment (2G1)

Methodology

Under an agreement with FOEN, the industry association SWISSMEM is reporting actual emissions of SF_6 on basis of a mass-balance approach (Tier 3a). The balance includes mainly data for the production, installation, operation and disposal of electrical equipment, but included in past years also small amounts of SF_6 for other applications (i.e. research, magnesium foundry). SWISSMEM is collecting data from its members and is cross-checking the reported SF_6 consumption data with data from importers of SF_6. Installations in operation with electrical equipment containing SF_6 are periodically inspected for leakage, and losses are refilled (topping up). The refilled quantities and any SF_6 charge required for during repair are reported as emissions at the time of filling. A product lifetime of 35 years is applied.

Emission Factors

Emission factors for this sub-source category are based on industry information and are calculated values based on the mass-balance data. For 2013 the calculated product life emission factor is 0.27% pear year. The calculated product life emission factor is varying between 0.77% per year (2005) and 0.1% per year (2011). The discontinuity in emission factor from 2005 to 2006 data is partly due to the inspection intervals, optimised data collection system and technical optimisation of equipment. The trend for reduced emission factors can be linked to the existing agreement of SWISSMEM and FOEN on the reduction of SF_6 emissions.

Activity Data

Activity data are based on industry information. The wide annual fluctuation of SF_6 emissions from electrical equipment is related to the annual fluctuation of market volumes for such equipment as well as variations in inspection intervals and equipment break-down requiring topping up of SF_6 charge in the equipment. Also for the inventory report 2013 (FOEN 2013) the split factors for allocation of imported amounts to different applications were checked through industry interviews and in-depth analysis in order to eliminate double counting between SWISSMEM data and other import declarations.

4.8.2.2 SF_6 and PFCs from other product use (2G2)

Methodology

The emissions reported under 2G2 are related to the use of SF_6 for industrial particle accelerators (2G2b), the use of SF_6 for soundproof windows (2G2c) and Other PFC and SF_6 use (2G2e). 2G2e summarizes research/analytics and further applications (including the unallocated difference of SF_6 between the FOEN import statistics and the SWISSMEM mass balance).

Under an agreement with FOEN, the industry association SWISSMEM is reporting actual emissions of SF_6 from industrial particle accelerators on the basis of a mass-balance approach (Tier 3a).

For 2G2c soundproof windows and 2G2e Other a Tier 2 approach was applied. Therefore, the unallocated amount of SF_6 under 2G2e has been assigned as application of cables and electrical control systems. Further evaluations of applications under 2G2e are based on FOEN import statistics and industry data, including applications with direct emissions and applications with banks. No further details are provided due to confidential data. Data are available from FOEN (confidential report Carbotech, 2015).

Emission Factors

For the unallocated amount of SF_6 assigned to cables and electrical control systems the manufacturing emission factor is assumed at 4% and the product life emission factor at 1% per year. 100% of the remaining charge is emitted at the time of disposal after 40 years lifetime. Because of the long lifetime the disposal emissions are not relevant for the given results.

For soundproof windows an annual emission rate of 1% is assumed, including the portion of broken windows. Since 2008 there is no production of windows with SF_6 in Switzerland. For the manufacturing in former years the emissions factor is assumed to be 33%.

Activity Data

Activity data are based on import statistics and industry information. For the unallocated amount of SF_6 assigned to cables and electrical control systems an export rate of 80% was assumed similar to electrical equipment 2G1. Also for the inventory report 2013 (FOEN 2013) the split factors for allocation of imported amounts to different applications was checked through industry interviews and in-depth analysis in order to eliminate double counting between SWISSMEM data and other import declarations. Interviews with industry were carried out for the present inventory to identify applications of substances related to research under Other (2G2e).

4.8.2.3 N_2O from product uses (2G3)

Methodology

Emissions of N_2O from the source category 2G3 occur from the anaesthesia use in hospitals (2G3a Medical applications) and from the use of aerosol cans in households (2G3b Other). For both categories a country-specific method based on the production/consumption of N_2O and of the different solvent applications is used.

Emission Factors

For source category 2G3a Medical applications the emission factor is calculated based on the amount of N_2O sold in Switzerland divided by the number of inhabitants. The yearly amount of N_2O sold for anaesthesia purpose is provided from sales information from the companies concerned based on annual data from 2005 onwards (EMIS 2015/2G3a Lachgasanwendung Spitäler).

Source category 2G3b Other includes N_2O emissions from whipped-cream makers using gas capsules for private households and restaurants. The emission factor is calculated based on sales figures and N_2O content of gas capsules sold in Switzerland divided by the number of inhabitants (EMIS 2015/2G3b Lachgasanwendung Haushalt).

In Table 4-44 emission factors for the emission of N_2O are given for the source categories 2G3a Medical applications and 2G3b Other.

Table 4-44 N_2O emission factors for the source categories 2G3a and 2G3b in g/inhabitant in 2013 (EMIS 2015/2G3a Lachgasanwendung Spitäler; EMIS 2015/2G3b Lachgasanwendung Haushalt).

2G3a Use of N_2O for anaesthesia	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
N_2O	g/inhabitant	43	40.4	37.7	35.1	32.5	29.8	27.2	24.5	21.9	19.3
2G3b N_2O from aerosol cans											
N_2O	g/inhabitant	9.3	9.3	9.4	9.4	9.5	9.6	9.6	9.7	9.7	9.8

2G3a Use of N_2O for anaesthesia	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
N_2O	g/inhabitant	16.6	14	13	13	12	12	10	9	8	7
2G3b N_2O from aerosol cans											
N_2O	g/inhabitant	9.8	9.9	9.9	10	10.3	10.5	10.8	11.0	11.3	11.5

2G3a Use of N_2O for anaesthesia	Unit	2010	2011	2012	2013
N_2O	g/inhabitant	7	6	5.8	5.6
2G3b N_2O from aerosol cans					
N_2O	g/inhabitant	11.8	12	12.2	12.4

Activity Data

For the source categories 2G3a Medical applications and 2G3b Other the activity data correspond to the Swiss population (SFSO 2014a) and amounts to 8'089'000 in 2013 (EMIS 2015/2G3a Lachgasanwendung Spitäler and EMIS 2015/2G3b Lachgasanwendung Haushalt).

Table 4-45 Activity data for the source categories 2G3a and 2G3b in 2013 (EMIS 2015/2G3a Lachgasanwendung Spitäler, EMIS 2015/2G3b Lachgasanwendung Haushalt).

2G3 N_2O from product uses	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
2G3a Use of N_2O for anaesthesia	inhabitants	6'796'000	6'880'000	6'943'000	6'989'000	7'037'000	7'081'000	7'105'000	7'113'000	7'132'000	7'167'000
2G3b N_2O from aerosol cans	inhabitants	6'796'000	6'880'000	6'943'000	6'989'000	7'037'000	7'081'000	7'105'000	7'113'000	7'132'000	7'167'000

2G3 N_2O from product uses	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
2G3a Use of N_2O for anaesthesia	inhabitants	7'209'000	7'285'000	7'343'000	7'405'000	7'454'000	7'501'000	7'558'000	7'619'000	7'711'000	7'801'000
2G3b N_2O from aerosol cans	inhabitants	7'209'000	7'285'000	7'343'000	7'405'000	7'454'000	7'501'000	7'558'000	7'619'000	7'711'000	7'801'000

2G3 N_2O from product uses	Unit	2010	2011	2012	2013
2G3a Use of N_2O for anaesthesia	inhabitants	7'878'000	7'912'000	7'997'000	8'089'000
2G3b N_2O from aerosol cans	inhabitants	7'878'000	7'912'000	7'997'000	8'089'000

4.8.2.4 Other (2G4)

In the following sections the NMVOC emissions from domestic solvent use (2D3a NFR), printing (2D3h NFR), other solvent use (2D3i NFR) as well as other product use (2G NFR) are reported. From other product use (2G NFR) also CO_2, NOx, CO and SO_2 from the use of fireworks are emitted.

Due to the obligations of the Ordinance on Air Pollution Control (Swiss Confederation 1985) and Ordinance on the Incentive Tax on Volatile Organic Compounds (Swiss Confederation 1997) several industrial plants use facilities and equipment to reduce NMVOC in exhaust gases and room ventilation output. Often this implies the feeding of air with high NMVOC content into the burning chamber of boilers or other facilities to incinerate NMVOC. This post-combustion of NMVOC leads to additional direct CO_2 emissions. They are estimated based on industry data and expert estimates (Carbotech 2014a).

Switzerland's Informative Inventory Report 2015 contains a description of the country-specific methods used for estimating the NMVOC emissions from the most important sources within source category 2G4 Other (FOEN 2015f).

Domestic solvent use (2D3a NFR)

Methodology

The emissions from source category 2G4 Domestic solvent use (2D3a NFR), which is the most important NMVOC emission source in 2G4 Other, are calculated proportional to the Swiss population. This source category comprises mainly the application of cleaning agents and solvents in private households for building and furniture cleaning and personal hygiene. The cleaning agents contain solvents which evaporate during use or after the application.

Emission Factors

For household cleaning, which is the most important emission source in source category 2G4 Other, the emission factor for NMVOC amounts to 960 g per inhabitant in 2013 (EMIS 2015/2G4 Reinigungs- und Lösemittel, Haushalte).

From 2001 until 2010 a constant EF of 900 g/inhabitant is assumed. The value is based both on information from the Swiss association of cosmetics and detergents (SKW 2010) and Theloke (2005). There were no significant improvements in the solvent compositions of the employed detergents. In a study conducted in 2013/2014 in Switzerland more accurate data of household cleaning agents, personal hygiene products an d domestic spray cans were collected. As a result of the study the emission factors were adjusted. Particularly the emission factor of source category 2G4 Domestic use of spray cans (2D3a NFR) increased significantly to 320 g/inhabitant (documented in EMIS 2015/2G4 Spraydosen Haushalte). For emission factors of 2013 see Table 4-46.

Table 4-46 Emission factors for NMVOC for source category 2G4 Other: domestic solvent use, printing, other solvent use, other product use in 2013 (EMIS 2015/2G4).

2G4 Other	Unit	NMVOC
Domestic solvent use (2D3a NFR)		
Domestic use of spray cans	g/inhabitant	320
Domestic use of pharmaceuticals	g/inhabitant	30
Household cleaning agents	g/inhabitant	960
Printing (2D3h NFR)		
Printing	kg/t ink	300
Package printing	kg/t ink	190
Other solvent use (2D3i NFR)		
Production of cosmetics	kg/employee	64
Production of paper and paperboard	g/t	35
Production of perfume and flavour	kg/employee	39
Production of textiles	kg/employee	8
Production of tobacco	kg/employee	12
Removal of paint and lacquer	g/inhabitant	35
Scientific laboratories	kg/employee	15
Other product use (2G NFR)		
Application of glues and adhesives	kg/t solvent	716
Commercial & industrial use of cleaning agents	g/employee	475
Cosmetic institutions	kg/employee	28
De-icing of airplanes	kg/t de-icing agent	280
Glass wool enduction	g/t glass wool	189
Hairdressers	kg/employee	14
Health care, other	kg/employee	8
Medical practices	kg/employee	8
Preservation of wood	kg/t preservative	110
Rock wool enduction	g/t rock wool	250
Underseal treatment & conservation of vehicles	kg/t underseal agent	400
Use of concrete additives	g/t additive	740
Use of cooling lubricants	kg/t lubricant	6
Use of lubricants	kg/t lubricant	340
Use of pesticides	kg/t pesticide	34
Use of tobacco	kg/Mio cigarette eq.	9

Activity Data

For 2G4 Domestic solvent use (2D3a NFR) the activity data used for calculating the NMVOC emissions correspond to the number of inhabitants in Switzerland and amounts to 8'089'000 in 2013 (EMIS 2015/2G4 Reinigungs- und Lösemittel, Haushalte). Further activity data are provided in Table 4-47.

Table 4-47 Activity data for source category 2G4 domestic solvent use, printing, other solvent use, other product use in 2013 (EMIS 2015/2G4).

2G4 Other	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Domestic solvent use (2D3a NFR)	inhabitants	6'796'000	6'880'000	6'943'000	6'989'000	7'037'000	7'081'000	7'105'000	7'113'000	7'132'000	7'167'000
Printing (2D3h NFR)											
Printing	t ink	12'600	12'750	12'900	13'050	13'200	13'350	13'500	13'650	13'800	13'850
Package printing	t ink	5'900	5'900	5'900	5'900	5'900	5'900	5'900	5'900	5'900	5'683
Other solvent use (2D3i NFR)											
Fat, edible & non-edible oil extraction	t	40'000	39'500	39'000	38'500	38'000	37'500	37'000	36'500	36'000	24'000
Production of cosmetics	employees	2'200	2'200	2'200	2'200	2'200	2'200	2'200	2'200	2'200	2'233
Production of paper and paperboard	t	1'510'000	1'520'000	1'530'000	1'540'000	1'550'000	1'560'000	1'570'000	1'580'000	1'590'000	1'750'000
Production of perfume and flavour	employees	2'200	2'225	2'250	2'275	2'300	2'325	2'350	2'375	2'400	2'483
Production of textiles	employees	25'200	25'513	25'825	26'138	26'450	26'763	27'075	27'388	27'700	26'000
Production of tobacco	employees	3'300	3'238	3'175	3'113	3'050	2'988	2'925	2'863	2'800	2'764
Removal of paint and lacquer	inhabitants	6'796'000	6'880'000	6'943'000	6'989'000	7'037'000	7'081'000	7'105'000	7'113'000	7'132'000	7'167'000
Scientific laboratories	employees	10'194	11'876	13'558	15'240	16'922	18'604	20'286	21'968	23'650	23'433
Vehicles dewaxing	vehicles	200'000	193'250	186'500	179'750	173'000	166'250	159'500	152'750	146'000	109'333
Other product use (2G NFR)											
Application of glues and adhesives	t	4'040	3'836	3'633	3'429	3'225	3'022	2'818	2'615	2'411	2'207
Commercial & industrial use of cleaning agents	employees	3'950'000	3'933'500	3'917'000	3'900'500	3'884'000	3'867'500	3'851'000	3'834'500	3'818'000	3'886'333
Cosmetic institutions	employees	2'600	2'700	2'800	2'900	3'000	3'100	3'200	3'300	3'400	3'467
De-icing of airplanes	t	1'300	1'300	1'300	1'300	1'300	1'300	1'300	1'300	1'300	1'300
Fireworks	t	840	790	810	810	840	1'030	1'000	800	1'290	1'850
Glass wool enduction	t	24'278	22'796	23'385	21'661	24'948	24'191	19'855	25'553	27'477	32'072
Hairdressers	employees	20'553	21'008	21'462	21'917	22'372	22'826	23'281	23'735	24'190	23'860
Health care, other	employees	113'000	116'250	119'500	122'750	126'000	129'250	132'500	135'750	139'000	142'333
Medical practices	employees	27'625	30'509	33'394	36'278	39'163	42'047	44'931	47'816	50'700	50'767
Preservation of wood	t paint	6'000	6'375	6'750	7'125	7'500	7'875	8'250	8'625	9'000	8'833
Rock wool enduction	t	38'375	39'277	38'468	35'108	36'655	39'745	37'259	34'723	40'339	45'119
Underseal treatment & conservation of vehicles	t	60	60	60	60	60	60	60	60	60	68
Use of concrete additives	t	24'000	24'250	24'500	24'750	25'000	25'250	25'500	25'750	26'000	27'333
Use of cooling lubricants	t	5'000	5'038	5'075	5'113	5'150	5'188	5'225	5'263	5'300	5'567
Use of lubricants	t	1'300	1'294	1'288	1'281	1'275	1'269	1'263	1'256	1'250	1'250
Use of pesticides	t	2'400	2'200	2'150	2'050	2'050	1'950	1'850	1'750	1'650	1'600
Use of tobacco	Mio cigarettes	16'192	16'334	17'195	16'173	15'816	15'774	15'502	15'130	15'411	14'856

2G4 Other	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Domestic solvent use (2D3a NFR)	inhabitants	7'209'000	7'285'000	7'343'000	7'405'000	7'454'000	7'501'000	7'558'000	7'619'000	7'711'000	7'801'000
Printing (2D3h NFR)											
Printing	t ink	13'900	13'950	11'600	9'250	6'900	5'467	4'033	2'600	2'533	2'467
Package printing	t ink	5'467	5'250	5'967	6'683	7'400	9'133	10'867	12'600	12'600	12'600
Other solvent use (2D3i NFR)											
Fat, edible & non-edible oil extraction	t	12'000	0	0	0	0	0	0	0	0	0
Production of cosmetics	employees	2'267	2'300	2'233	2'167	2'100	2'100	2'100	2'100	2'100	2'100
Production of paper and paperboard	t	1'780'000	1'750'000	1'800'000	1'820'000	1'780'000	1'750'000	1'690'000	1'734'000	1'700'000	1'540'000
Production of perfume and flavour	employees	2'567	2'650	2'800	2'950	3'100	3'200	3'300	3'400	3'425	3'450
Production of textiles	employees	24'300	22'600	20'867	19'133	17'400	17'067	16'733	16'400	16'200	14'200
Production of tobacco	employees	2'729	2'693	2'695	2'698	2'700	2'710	2'705	2'700	2'825	2'950
Removal of paint and lacquer	inhabitants	7'209'000	7'285'000	7'343'000	7'405'000	7'454'000	7'501'000	7'558'000	7'619'000	7'711'000	7'801'000
Scientific laboratories	employees	23'217	23'000	23'000	23'000	23'000	23'000	23'000	23'000	23'000	23'000
Vehicles dewaxing	vehicles	72'667	36'000	0	0	0	0	0	0	0	0
Other product use (2G NFR)											
Application of glues and adhesives	t	2'004	1'800	1'727	1'653	1'580	1'483	1'387	1'290	1'264	1'238
Commercial & industrial use of cleaning agents	employees	3'954'667	4'023'000	4'035'000	4'047'000	4'059'000	4'133'667	4'208'333	4'283'000	4'323'333	4'363'667
Cosmetic institutions	employees	3'533	3'600	3'667	3'733	3'800	3'800	4'000	4'200	4'400	4'600
De-icing of airplanes	t	1'300	1'300	1'850	2'400	2'950	2'533	2'117	1'700	2'380	3'060
Fireworks	t	1'520	1'261	1'861	1'884	1'977	1'358	1'546	1'746	1'951	1'990
Glass wool enduction	t	31'052	25'207	19'922	25'885	32'708	37'483	38'060	44'487	44'364	33'467
Hairdressers	employees	23'530	23'200	22'967	22'733	22'500	22'200	22'200	22'200	23'000	23'000
Health care, other	employees	145'667	149'000	152'667	156'333	160'000	161'667	163'333	165'000	163'000	163'000
Medical practices	employees	50'833	50'900	52'014	53'129	54'243	55'357	56'471	57'586	58'700	58'700
Preservation of wood	t paint	8'667	8'500	8'100	7'700	7'300	7'167	7'033	6'900	7'000	7'100
Rock wool enduction	t	50'567	45'160	46'621	44'282	47'820	46'270	52'559	62'756	57'761	52'966
Underseal treatment & conservation of vehicles	t	76	85	93	101	109	118	126	134	142	150
Use of concrete additives	t	28'667	30'000	32'333	34'667	37'000	36'000	35'000	34'000	34'000	34'000
Use of cooling lubricants	t	5'833	6'100	6'100	6'100	7'100	6'375	5'650	4'925	4'200	2'800
Use of lubricants	t	1'250	1'250	2'433	3'617	4'800	3'700	2'600	1'500	400	290
Use of pesticides	t	1'700	1'700	1'643	1'587	1'530	1'520	1'510	1'500	1'675	1'850
Use of tobacco	Mio cigarettes	14'751	14'427	14'400	15'351	15'052	13'369	13'808	13'072	13'310	13'667

Table 4-47 continued: Activity data for source category 2G4 domestic solvent use, printing, other solvent use, other product use in 2013 (EMIS 2015/2G4).

2G4 Other	Unit	2010	2011	2012	2013
Domestic solvent use (2D3a NFR)	inhabitants	7'878'000	7'912'000	7'997'000	8'089'000
Printing (2D3h NFR)					
Printing	t ink	2'400	2'377	2'353	2'330
Package printing	t ink	12'600	12'783	12'967	13'150
Other solvent use (2D3i NFR)					
Fat, edible & non-edible oil extraction	t	0	0	0	0
Production of cosmetics	employees	2'100	2'100	2'100	2'100
Production of paper and paperboard	t	1'540'000	1'380'000	1'422'500	1'465'000
Production of perfume and flavour	employees	3'475	3'500	3'521	3'542
Production of textiles	employees	13'800	14'800	14'875	14'950
Production of tobacco	employees	3'075	3'200	3'200	3'200
Removal of paint and lacquer	inhabitants	7'878'000	7'912'000	7'997'000	8'089'000
Scientific laboratories	employees	23'000	23'000	23'083	23'167
Vehicles dewaxing	vehicles	0	0	0	0
Other product use (2G NFR)					
Application of glues and adhesives	t	1'212	1'185	1'159	1'133
Commercial & industrial use of cleaning agents	employees	4'404'000	4'333'333	4'262'667	4'192'000
Cosmetic institutions	employees	4'800	5'000	5'111	5'222
De-icing of airplanes	t	3'740	4'420	5'100	5'100
Fireworks	t	1'685	2'017	1'928	2'327
Glass wool enduction	t	35'698	41'414	38'747	33'350
Hairdressers	employees	23'000	23'000	23'000	23'000
Health care, other	employees	163'000	163'000	163'000	163'000
Medical practices	employees	58'700	58'700	58'700	58'700
Preservation of wood	t paint	7'200	7'312	7'424	7'536
Rock wool enduction	t	56'376	57'413	56'959	54'094
Underseal treatment & conservation of vehicles	t	159	167	175	175
Use of concrete additives	t	41'000	44'000	38'000	38'000
Use of cooling lubricants	t	3'600	4'000	3'700	3'700
Use of lubricants	t	350	490	370	370
Use of pesticides	t	2025	2200	2200	2200
Use of tobacco	Mio cigarettes	12443	11856	12705	11944

Printing (2D3h NFR)

Methodology

The source category 2G4 Printing (2D3h NFR) has been split into 2G4 Printing and 2G4 Package printing. Country-specific methods are applied for calculating the NMVOC emissions from the ink applications.

Emission factors

The splitting of source category 2D3h Printing into 2D3h Printing and 2D3h Package printing resulted in small rounding changes in the NMVOC EF values for the entire time series 1990-2012. Emission factors for NMVOC are country specific based on data from industry, industry associations, German studies on NMVOC emissions from solvent use (Theloke J. 2005) and expert estimates, as documented in the EMIS database (EMIS 2015/2G4). For emission factors of 2013 see Table 4-46.

Activity Data

The activity data used for calculating the NMVOC emissions correspond to the annual consumption of printing ink. This data stem from industry associations and expert estimates, documented in the EMIS database (EMIS 2015/2G4). For activity data see Table 4-47.

Other solvent use (2D3i NFR)

Methodology

For source category 2G4 Other solvent use (2D3i NFR) country specific methods based on information from industry and services, industry associations, German studies on NMVOC emissions from solvent use (Theloke et al. 2000, Theloke J. 2005) and expert estimates are applied for calculating the emissions from the different solvent applications. For one part of the production processes – such as 2G4 Production of paper and paperboard (2D3i NFR) – the NMVOC emissions are calculated on the basis of production volume. For the other part of production processes – such as 2G4 Production of perfume and flavour (2D3i NFR) and 2G4 Production of textiles (2D3i NFR) the NMVOC emissions are estimated based on the respective number of employees. The quantity of NMVOC emission per employee originates from the bottom-up approach in these industrial sectors and the decentralized political structure in Switzerland. The determined NMVOC emissions of representative production sites or service institutions are referred to the number of employees in order to calculate the Swiss total. For the source category 2G4 Not attributable solvent emissions (2D3i NFR) so-called direct emission data are available only.

Emission factors

Emission factors for NMVOC are country specific based on data from industry and services, industry associations, German studies on NMVOC emissions from solvent use (Theloke et al. 2000 and Theloke J. 2005) and expert estimates, as documented in the EMIS database (EMIS 2014/2G4). For emission factors of 2013 see Table 4-46.

Activity Data

The activity data used for calculating the NMVOC emissions, correspond to the annual production volumes, the number of employees and the Swiss population (SFSO 2014a). This data stem from industry, services, industry associations and expert estimates, documented in the EMIS database (EMIS 2015/2G4). For activity data see Table 4-47.

Other product use (2G NFR)

Methodology

For source category 2G4 Other product use (2G NFR) country specific methods based on information from industry and services, industry associations, German studies on NMVOC emissions from solvent use (Theloke et al. 2000, Theloke J. 2005) and expert estimates are used for calculating the emissions from the different solvent applications. For one part of the production processes – such as 2G4 Enduction of glass and rock wool (2G NFR) – and applications – such as 2G4 Preservation of wood (2G NFR) and 2G4 Application of glues and adhesives (2G NFR) – the NMVOC emissions are calculated on the basis of production volume or employed agents. For the other part – such as 2G4 House cleaning in services, commerce and industry (2G NFR) and 2G4 Medical practices (2G NFR) – the NMVOC emissions are estimated based on the respective number of employees. The quantity of NMVOC emission per employee originates from the bottom-up approach in these industrial and service sectors and the decentralized political structure in Switzerland. The determined NMVOC emissions of representative production sites or service institutions are referred to the number of employees in order to calculate the Swiss total. For the source categories 2G4 (2G NFR) Gas applications, Renovation of corrosion inhibiting coatings and Use of aerosol cans in commerce and industry so-called direct emission data are available only.

Emission factors

Emission factors for NMVOC are country specific based on data from industry and services, industry associations, German studies on NMVOC emissions from solvent use (Theloke et al. 2000 and Theloke J. 2005) and expert estimates, as documented in the EMIS database (EMIS 2015/2G4). For emission factors of 2013 see Table 4-46.

Emission factors other than NMVOC for source category 2G4 Fireworks (2G NFR) are provided in Table 4-48 and based on data from Swiss industry and expert estimates, documented in the EMIS database (EMIS 2015/2G4).

Table 4-48 Emission factors for CO_2, NOx, CO, SO_2 for source category 2G4 Fireworks in 2013 (EMIS 2015/2G4 Feuerwerke).

2G4 Other	Unit	CO_2	NOx	CO	SO_2
Other product use (2G NFR)					
Fireworks	kg/t	43	0.26	7.4	4.1

Activity Data

The activity data used for calculating the emissions, correspond to the annual production volumes, consumption of solvents and agents and the number of employees. These data stem from industry, services, industry associations and expert estimates, documented in the EMIS database (EMIS 2015/2G4). For activity data see Table 4-47.

HFC not accounted in other source categories

Emissions of HFC not corresponding to other source categories are accounted under 2G4 Other. For confidentiality reasons no further details are provided. Information is available from FOEN (confidential report Carbotech, 2015).

Methodology

A Tier 2 approach has been applied for HFCs with prompt emissive applications based on import statistics and industry data.

Emission factors

Prompt emissions of HFC were calculated following 2006 IPCC Guidelines assuming an emission factor of 50% in the first year and 50% in the second year (total loss of product within two years).

Activity Data

HFC activity data under 2G4 are based on FOEN import statistic and industry data.

4.8.3 Uncertainties and Time-Series Consistency

The uncertainty of total CO_2 emissions from the entire source category 2G is estimated at 50% (expert estimate).

The uncertainty of N_2O emissions from source category 2G which is a key category for this gas regarding trend according to approach 2 is estimated at 80% (expert estimate, see Table 1-11).

The uncertainty of CO_2eq from emissions SF_6, PFC and HFC in source category 2G amounts to 14% (HFC 16%, PFC 9%, SF_6 17%), which is the result of a Monte Carlo Analysis (Carbotech, 2015). Source category 2G is a key category for SF_6 and HFC regarding level and trend, respectively according to approach 1.

Time series is consistent, with exception of the sub-source category Electrical Equipment (2G2) where from 2000 onwards the data are based on a Tier 3a approach instead of model calculations according to Tier 2 as applied for data before 2000. Due to lack of basic information it is not possible to provide a consistent time series for category Electrical Equipment (2G2) retroactively.

4.8.4 Source-Specific QA/QC and Verification

The general QA/QC measures are described in section 1.2.3.

4.8.5 Source-Specific Recalculations

- Interviews with industry were carried out to improve model calculations of HFC, PFC and SF_6 emissions under 2G2e and 2G4 (no details are given for confidentiality reason). New GWP values were applied for PFC, HFC and SF_6 following the 2006 IPCC Guidelines.
- The NMVOC EF for 2G4 (2D3a NFR) Household cleaning agents has been updated for 2013 resulting in revised interpolated EF values for 2011 and 2012.
- The NMVOC EF for 2G4 (2D3a NFR) Domestic use of spray cans has been updated for 2013 resulting in revised interpolated EF values between 2008 and 2012.
- The source category 2G4 (2D3h NFR) Printing has been split into 2G4 Printing and 2G4 Package printing resulting in small rounding changes in the NMVOC EF values for the

entire time series 1990-2012. The AD have been updated for 2013 yielding revised interpolated values for 2011 and 2012.

- The NMVOC EF for 2G4 (2D3i NFR) Removal of paint and lacquer has been updated for 2013 resulting in revised interpolated EF values for 2011 and 2012.
- For 2G4 (2D3i NFR) Production of cosmetics the AD has been updated for 2013 resulting in revised interpolated values for 2011 and 2012 whereas the NMVOC EF has been revised for the entire time series 1990-2012.
- The AD of 2G4 (2G NFR) fireworks has been revised from 2001 onwards. AD is now based on the fedpol statistics of pyrotechnics (FEDPOL 2014).
- The EF of NMVOC from 2G4 (2G NFR) Mineralwool enduction has been revised for 2009-2012 based on air pollution control measurements.
- The AD and NMVOC EF for 2G4 (2G NFR) Commercial and industrial use of cleaning agents have been updated for 2013 resulting in revised interpolated values for 2011 and 2012.

4.8.6 Source-Specific Planned Improvements

No source-specific improvements are planned.

4.9 Source Category 2H – Other

4.9.1 Source Category Description

Source category 2H Other comprises process emissions of precursors from the production of pulp and paper including chipboard, fibreboard and cellulose as well as of food and beverage. Biogenic CO_2 emissions from the production of beer, brandy, bread and wine within source category 2H2 Food and beverages industry are not reported. In addition

source category 2H Other also comprises process emissions from blasting and shooting and Claus units in refineries.

Table 4-49 Specification of source category 2H Other. EMIS 2015/… refers to the internal documentation of the emission database and contains further references regarding specific AD and/or EF.

2H	Source	Specification	Data Source
2H1	Pulp and paper	Emissions from NMVOC from pulp and paper including chipboard, fibreboard and cellulose production (ceased in 2008)	AD, EF: EMIS 2015/2H1
2H2	Food and beverages industry	Emissions of CO and NMVOC from production of food and drink	AD, EF: EMIS 2015/2H2
2H3	Other	Emissions of CO_2, NOx, CO, NMVOC and SO_2 from blasting and shooting; Emissions of SO_2 from Claus units in refineries	AD, EF: EMIS 2015/2H3 Sprengen und Schiessen AD, EF: SFOE 2014, expert estimates

4.9.2 Methodological Issues

4.9.2.1 Pulp and paper (2H1)

Methodology

In 2013 the production of chipboard and fibreboard are the relevant industrial processes in the source category 2H1 Pulp and paper. In Switzerland chipboard and fibreboard are produced in one and two plants, respectively. The cellulose production was closed down in 2008 and is not occurring anymore in Switzerland.

For all source categories country-specific approaches are used. The emissions are calculated by multiplying the annual production output by emission factors.

Emission Factors

The emission factor for NMVOC emissions from pulp and paper production in Switzerland is country-specific and based on measurements and data from industry and expert estimates documented in EMIS 2015/2H1. The implied emission factor is production-weighted and related to chipboard and fibreboard production (see Table 4-50).

Table 4-50 Emission factors for CO and NMVOC in pulp and paper production and food and beverages industry, CO_2, NOx, CO, NMVOC and SO_2 from blasting and shooting and SO_2 from Claus units in refineries for 2013 (EMIS 2015/2H1, EMIS 2015/2H2 and EMIS 2015/2H3).

2H Other	Unit	CO_2	NO_x	CO	NMVOC	SO_2
2H1 Pulp and paper	g/t	NA	NA	NA	570	NA
2H2 Food and beverages industry (exc. beer, wine, spirits)	g/t	NA	NA	250	1'230	NA
2H2 Food and beverages industry (beer, wine, spirits)	g/m3	NA	NA	NA	350	NA
2H3 Blasting and shooting	kg/t	400	35	310	60	0.5
2H3 Claus units in refineries	g/t	NA	NA	NA	NA	38

Activity Data

The annual amount of pulp and paper produced in Switzerland is based on data from industry and expert estimates documented in EMIS 2015/2H1 (see Table 4-51).

Table 4-51 Pulp and paper production, food and beverages production, amount of used explosives and processed crude oil in Switzerland for the period 1990-2013 in Gg and m³ (EMIS 2015/2H1, EMIS 2015/2H2, EMIS 2015/2H3 and SFOE 2014).

2H Other	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
2H1 Pulp and paper	Gg	604	608	663	668	632	593	567	586	615	629
2H2 Food and beverages industry (exc. beer, wine, spirits)	Gg	2'254	2'253	2110	2186	2092	2116	2240	2167	2177	2061
2H2 Food and beverages industry (beer, wine, spirits)	m3	560'972	581'643	579'714	546'882	531'068	516'519	497'401	505'873	461'979	476'067
2H3 Blasting and shooting; blasting agent and powder	Gg	2.6	2.3	2.1	1.8	1.6	1.3	0.5	0.8	1.1	1.6
2H3 Claus units in refineries; Crude oil	Gg	3'127	4'671	4'317	4'764	4'880	4'657	5'290	4'984	5'070	5'093

2H Other	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
2H1 Pulp and paper	Gg	641	640	645	634	652	660	696	752	728	514
2H2 Food and beverages industry (exc. beer, wine, spirits)	Gg	2'301	2'083	2'276	2'246	2'153	2'138	2'167	2'344	2'428	2'437
2H2 Food and beverages industry (beer, wine, spirits)	m3	492'208	481'114	466'112	461'071	475'754	452'877	451'924	462'141	479'293	465'753
2H3 Blasting and shooting; blasting agent and powder	Gg	1.9	2.0	3.3	4.1	3.6	0.8	1.5	1.1	1.4	2.1
2H3 Claus units in refineries; Crude oil	Gg	4'649	4'927	4'924	4'642	5'219	4'877	5'563	4'720	5'133	4'833

2H Other	Unit	2010	2011	2012	2013
2H1 Pulp and paper	Gg	570	534	502	482
2H2 Food and beverages industry (exc. beer, wine, spirits)	Gg	2'400	2'483	2'418	2'388
2H2 Food and beverages industry (beer, wine, spirits)	m3	467'699	462'446	454'903	449'070
2H3 Blasting and shooting; blasting agent and powder	Gg	2.4	2.9	2.3	2.2
2H3 Claus units in refineries; Crude oil	Gg	4'546	4'452	3'455	4'935

4.9.2.2 Food and beverages industry (2H2)

Methodology

To determine CO and NMVOC emissions from food and beverages industry a country-specific approach is used. The emissions are calculated by multiplying the annual amount of produced food and beverages by the corresponding emission factors.

Emission Factors

The emission factors for CO and NMVOC emissions from food and beverages industry in Switzerland are country-specific and based on measurements and data from industry and expert estimates documented in EMIS 2015/2H2. The implied emission factors are production-weighted values and disclosed in Table 4-50.

Activity Data

The annual amount of food and beverages produced in Switzerland is based on data from industry, farmers' association and expert estimates documented in EMIS 2015/2H2 (see Table 4-51).

4.9.2.3 Other (2H3)

Blasting and shooting and Claus units in refineries (2H3)

Methodology

For determination of emissions of CO_2, NOx, CO, NMVOC and SO_2 from blasting and shooting a country-specific method is used as documented in EMIS 2015/2H3 Sprengen und Schiessen. The emissions are calculated by multiplying the annual amount of used explosive by the corresponding emission factors. The SO_2 emissions from Claus units are calculated by multiplying the annual amount of processed crude oil by the emission factor.

Emission Factors

The emission factors for CO_2, NOx, CO, NMVOC and SO_2 from blasting and shooting activities in Switzerland and for SO_2 emissions from Claus units in refineries are country-specific and based on measurements and data from industry and expert estimates documented in EMIS 2015/2H3 Sprengen und Schiessen (see Table 4-50).

Activity Data

The annual amount of used explosives and of processed crude oil in Claus units is based on the Federal statistics on explosives as documented in EMIS 2015/2H3 Sprengen und Schiessen and the Swiss overall energy statistics (SFOE 2014), respectively (see Table 4-51).

4.9.3 Uncertainties and Time-Series Consistency

The uncertainty for CO_2 emissions from 2H Other is rated medium (see Table 1-11, semi-quantitative uncertainties for non-key categories) and thus amounts to 10%.

Consistency: Time series for 2H Other are all considered consistent.

4.9.4 Source-Specific QA/QC and Verification

The general QA/QC measures are described in section 1.2.3.

4.9.5 Source-Specific Recalculations

2H1 Pulp and paper: The AD of 2H1 Fibre board production for 2012 has been corrected due to a mistake in last year's submission.

4.9.6 Source-Specific Planned Improvements

No source-specific improvements are planned.

5 Agriculture

5.1 Overview

This chapter provides information on the estimation of the greenhouse gas emissions from the sector Agriculture. The following source categories are reported:

- 3A Enteric fermentation, CH_4 emissions from domestic livestock,
- 3B Manure management, emissions of CH_4, N_2O and NO_x,
- 3D Agricultural soils, emissions of N_2O, NO_x and NMVOC,
- 3G Liming, emissions of CO_2
- 3H Urea application; emission of CO_2

Categories 3C Rice cultivation, 3E Prescribed burning of savannahs and 3F Field burning of agricultural residues do not occur in Switzerland and are therefore not reported.

CO_2 emissions from soils are reported under Land use, land-use change and forestry. CO_2 emissions from energy use in agriculture are reported under 1A4c Agriculture/forestry/fishing.

Total greenhouse gas emissions from the agriculture sector in 2013 were 5'949 kt CO_2 equivalents which is a contribution of 11.3% to the total of Swiss greenhouse gas emissions (excluding LULUCF,Table 2-1, Table 5-1). Main agricultural sources of greenhouse gases in 2013 were Enteric fermentation, emitting 3'239 kt CO_2 equivalents (54% of all agricultural greenhouse gases), followed by Agricultural soils with 1'543 kt CO_2 equivalents (26%) and Manure management with 1'126 kt CO_2 equivalents (19%)(Figure 5-1). Liming and Urea application contributed 33 kt CO_2 equivalents (0.5%) and 9 kt CO_2 equivalents (0.1%) respectively.

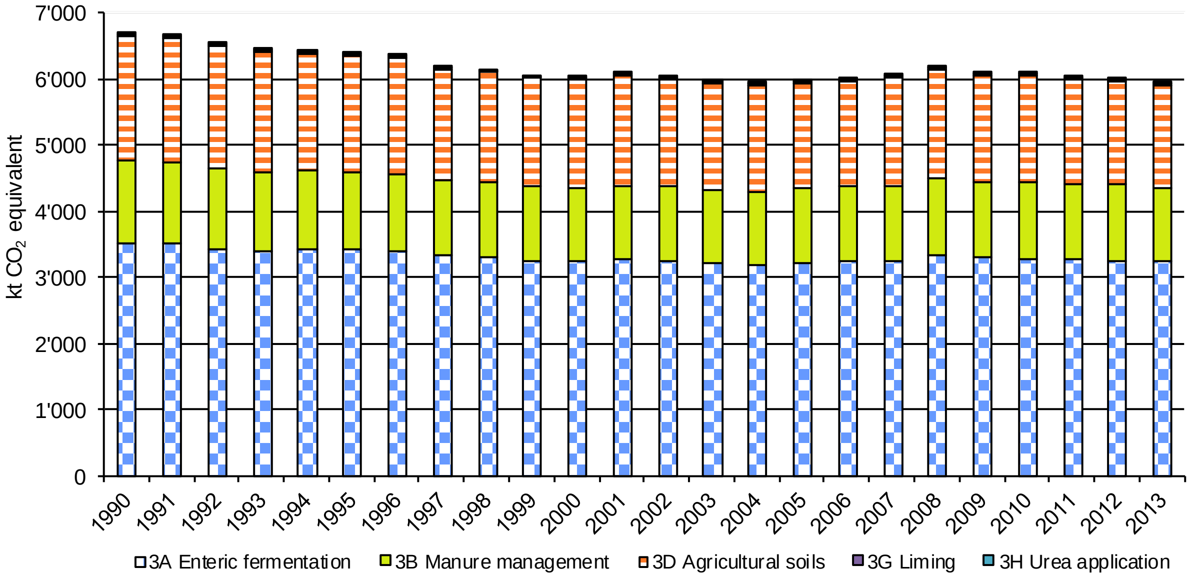


Figure 5-1 Greenhouse gas emissions of the agriculture sector in kt CO_2 equivalents 1990-2013.

Table 5-1 Greenhouse gas emissions in kt CO_2 equivalents from agriculture 1990-2013.

Gas	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
	kt CO_2 equivalent									
CO_2	49	42	42	42	42	42	42	38	36	37
CH_4	4'420	4'406	4'319	4'265	4'286	4'275	4'241	4'145	4'113	4'055
N_2O	2'244	2'226	2'195	2'149	2'112	2'096	2'084	2'000	1'992	1'962
Sum	6'713	6'674	6'557	6'456	6'440	6'413	6'367	6'182	6'141	6'055

Gas	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
	kt CO_2 equivalent									
CO_2	39	40	41	39	44	42	41	46	43	41
CH_4	4'028	4'061	4'033	3'993	3'962	3'997	4'029	4'048	4'149	4'093
N_2O	1'962	1'988	1'980	1'943	1'948	1'953	1'952	1'982	1'988	1'957
Sum	6'029	6'089	6'054	5'976	5'954	5'993	6'022	6'076	6'180	6'091

Gas	**2010**	**2011**	**2012**	**2013**
	kt CO_2 equivalent			
CO_2	44	43	41	42
CH_4	4'073	4'054	4'039	3'999
N_2O	1'991	1'955	1'935	1'909
Sum	6'108	6'052	6'015	5'949

CH_4 and N_2O emissions generally declined from 1990 until 2013 with a distinct rise during the years 2004 and 2008 (Figure 5-2). This general development can be explained by the changes in the cattle population and the input of mineral fertilisers. Use of mineral fertiliser declined due to the introduction of the “Proof of Ecological Performance (PEP)” in the early 1990s (ART 2013a, Leifeld and Fuhrer 2005), while the cattle population was influenced by the market situation, the milk quotation system (suspended in 2009) and the general agricultural policy- and subsidy-system (OECD 2013). Most emission factors did not change significantly over the inventory years.

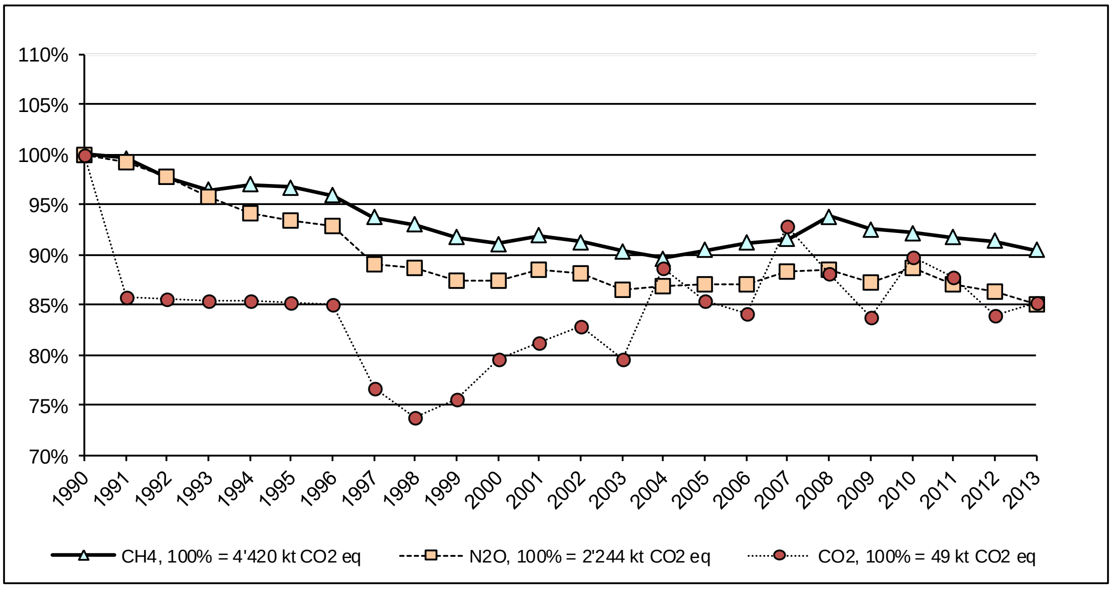


Figure 5-2 Trend of the greenhouse gases of the agricultural sector 1990-2013. The base year 1990 represents 100%.

Among the key categories of the Swiss inventory, five are from the agricultural sector (Figure 5-3).

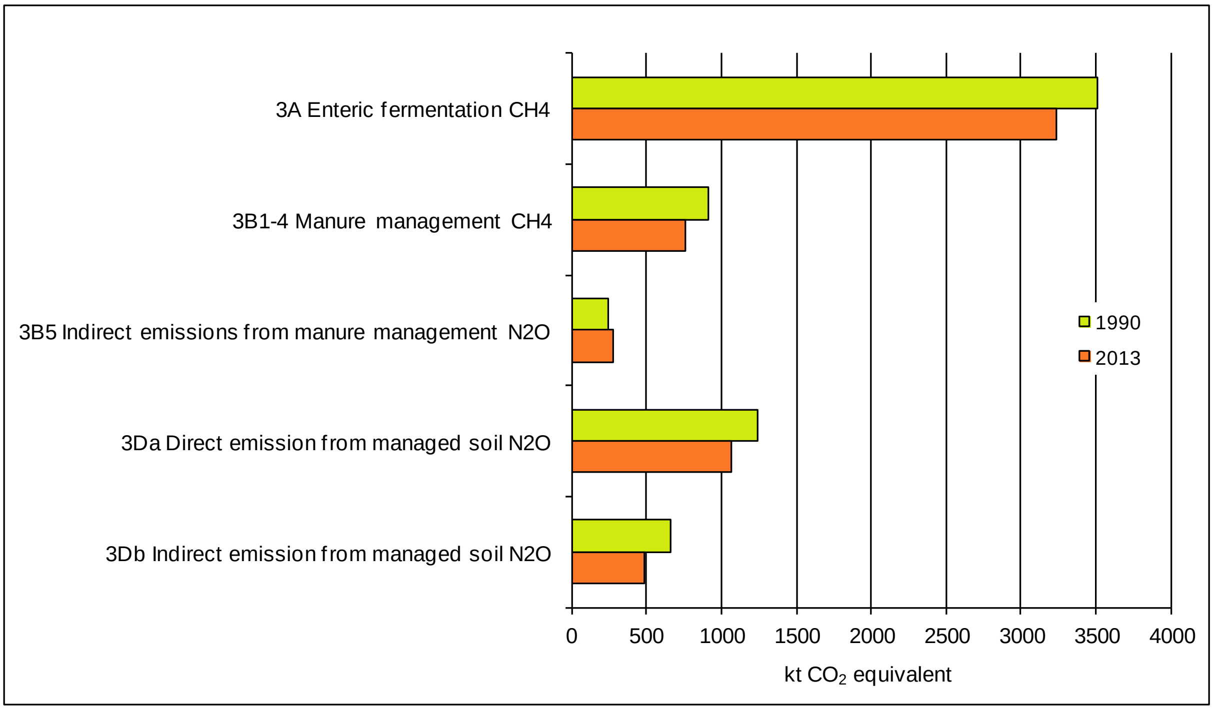


Figure 5-3 Key categories (Approach 1 and Approach 2) in agriculture 1990 and 2013.

5.2 Source Category 3A – Enteric Fermentation

5.2.1 Source Category Description

Approach 1 and Approach 2 Key Category 3A
CH_4 emissions from Enteric fermentation (level and trend)

This emission source comprises the domestic livestock population broken down into 3 cattle categories (mature dairy cattle, other mature cattle, growing cattle), sheep, swine, buffalo, camels, deer, goats, horses, mules and asses, poultry, rabbits and livestock not covered by the agricultural census (livestock NCAC)(Table 5-2).

Emissions from Enteric fermentation declined from 1990 until 2004, mainly due to a reduction in the number of cattle. However, between 2004 and 2008 cattle livestock numbers and subsequently CH_4 emissions increaed, whereas since 2008 they have been decreasing again. Cattle contribute over 93% to the overall emissions from Enteric fermentation.

Table 5-2 Specification of source category 3A Enteric fermentation. (AD: Activity data; EF: Emission factor).

3A	Source	Specification	Data Source
3A1	Cattle	Mature Dairy Cattle	AD: SBV 2014, ART/SHL 2012, SFSO 2014d EF: Soliva 2006, IPCC 2006, Agroscope 2014c, Zeitz et al. 2012, Estermann et al. 2001, Külling et al. 2002, Staerfl et al. 2012; net energy and metabolisable energy (calves) from RAP 1999
		Other Mature Cattle	
		Growing Cattle (Fattening Calves, Pre-Weaned Calves, Breeding Cattle 1st year (Breeding Calves + Breeding Cattle 4-12 months), Breeding Cattle > 1 year, Fattening Cattle (Fattening Calves 0-4 months, Fattening Cattle 4-12 months))	
3A2 3A3 3A4d	Sheep Swine Goats	Lambs < 1 year Mature Sheep	AD: SBV 2014, ART/SHL 2012, SFSO 2014d EF: Soliva 2006, IPCC 2006, Crutzen et al. 1986, Martínez-Fernández 2014 and Fernández et al. 2013; net energy data from Giuliani 2014
3A4a 3A4b 3A4c	Buffalo Camels Deer	Bisons < 3 years Bisons > 3 years Llamas < 2 years Llamas > 2 years Alpacas < 2 years Alpacas > 2 years Fallow Deer Red Deer	AD: SBV 2014, SFSO 2014d EF: IPCC 2006; gross energy intake from Flisch et al. 2009
3A4e 3A4f	Horses Mules and Asses	Horses < 3 years Horses > 3 years Mules Asses	AD: SBV 2014, ART/SHL 2012, SFSO 2014d EF: Vermorel et al. 1997, Minonzio et al. 1998; digestible energy data from Stricker 2012
3A4g	Poultry		AD: SBV 2014, ART/SHL 2012, SFSO 2014d EF: Hadorn and Wenk 1996 cited in Soliva 2006; net energy data from Giuliani 2014
3A4h i	Rabbits		AD: SBV 2014, SFSO 2014d EF: ISPRA 2014; energy intake Menzi 2014 based on Schlegel and Menzi 2013
3A4h ii	Livestock NCAC	Sheep Goats Horses < 3 years Horses > 3 years Mules Asses	AD: SFSO 2014e EF: as above

5.2.2 Methodological Issues

5.2.2.1 Methodology

Assessment of CH_4 emissions from Enteric fermentation is based on methods described in the 2006 IPCC Guidelines (equation 10.21). Emission estimation generally followed a Tier 2 approach. This means that detailed country-specific data on nutrient requirements, feed intake and CH_4 conversion rates for specific animals and feed types were used. For mature dairy cattle a more detailed feeding model was applied, predicting gross energy intake based on animal performance and diet chemical composition. A country-specific methane conversion rate (Y_m) for mature dairy cattle was derived from a series of studies representing Swiss specific feeding conditions.

The calculation of CH_4 emissions is conducted in Agroscope (2015).

5.2.2.2 Emission Factors

All emission factors for Enteric fermentation are country-specific, based on IPCC equation 10.21 (IPCC 2006):

$$EF = \frac{GE * (Y_m \div 100) * 365\, days / y}{55.65\, MJ / kg\, CH_4}$$

EF = annual CH_4 emission factor (kg/head/year)

GE = gross energy intake (MJ/head/day)

Y_m = methane conversion rate, which is the fraction of gross energy in feed converted to methane (%)

55.65 MJ/kg = energy content of methane.

Gross energy intake (GE)

For calculating the gross energy intake (GE), country-specific methods based on available data on requirements of net energy, digestible energy and metabolisable energy were applied. The different energy levels used for energy conversion from energy required for maintenance and production to GE intake are illustrated in Figure 5-4. The respective conversion factors are given in Table 5-3.

For the **cattle categories** detailed estimations for energy requirements are necessary. As the Swiss Farmers Union (SBV) does not provide these estimates on a detailed cattle sub-category level, requirements for each cattle source category were calculated individually following the feeding recommendations for Switzerland provided in RAP (1999). These RAP recommendations are also used by the Swiss farmers as the basis for their cattle feeding regimes and for filling in application forms for direct payments; they are therefore highly appropriate.

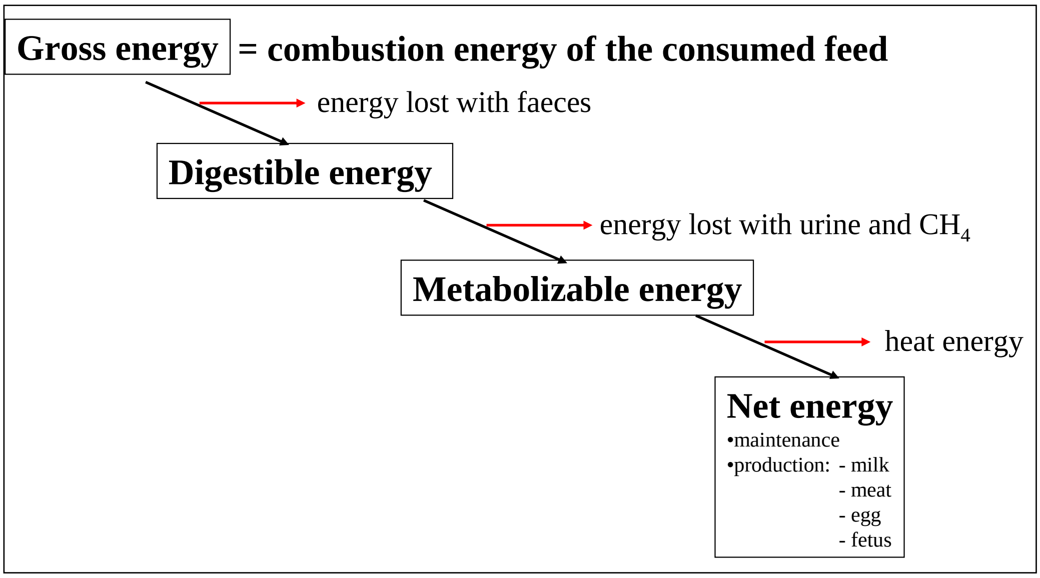


Figure 5-4 Levels of feed energy conversion (Soliva 2006).

Table 5-3 Conversion factors used for calculation of energy requirements of individual livestock categories (Soliva 2006). GE: Gross energy; DE: Digestible energy; ME: Metabolisable energy; NEL: Net energy for lactation; NEV: Net energy for growth. Blue: annually changing parameters, value for 2013.

Livestock Category		**Conversion Factors**	
Mature Dairy Cattle		NEL to GE	0.340
Other Mature Cattle		NEL to GE	0.275
Growing Cattle	*Fattening Calves*	*ME to GE*	*0.930*
	Pre-Weaned Calves	*NEL to GE*	*0.291*
	Breeding Calves	*NEL to GE*	*0.341*
	Breeding Cattle (4-12 months)	*NEL to GE*	*0.322*
	Breeding Cattle (> 1 year)	*NEL to GE*	*0.313*
	Fattening Calves (0-4 months)	*NEV to GE*	*0.350*
	Fattening Cattle (4-12 months)	*NEV to GE*	*0.401*
Sheep	*Fattening Sheep*	*NEV to GE*	*0.350*
	Milksheep	*NEL to GE*	*0.287*
Swine		DE to GE	0.682
Buffalo		NA	NA
Camels		NA	NA
Deer		NA	NA
Goats		NEL to GE	0.283
Horses		DE to GE	0.700
Mules and Asses		DE to GE	0.700
Poultry		ME to GE	0.700
Rabbits		NA	NA
Livestock NCAC		NA	NA

For **mature dairy cattle** a detailed feeding model from the Agroscope Institute for Livestock Sciences was used to predict gross energy intake (Agroscope 2014c). Energy and protein requirements were estimated based on animal performance (body weight, milk production, pregnancy) following the standard feeding recommendations for Switzerland (RAP 1999).

To cover total animal energy and protein requirements, typical Swiss specific basic feed rations were defined as model inputs. Basic feed ration in summer consisted of 92% fresh grass and 8% maize cubes. In winter the feed ration consisted of 10% maize silage, 13% grass silage, 72% hay and 5% fodder beet. Concentrates are automatically supplemented in the model according to additional energy and protein requirements not covered by the basic feed ration. Concentrates consisted of a varying mixture of barley grains, wheat grains, maize grains, maize gluten, soybean meal and rapeseed meal according to specific animal requirements. Subsequently, average chemical composition and properties of the total feed ration (e.g. energy content, protein content, digestibility) were derived, weighing the respective values of the individual feed ingredients given in the Swiss Feed Database (Agroscope 2014b). Finally, gross energy intake was estimated based on the total feed intake and the gross energy content of the total ration that was 18.26 MJ/kg on average for the years 1990-2013.

Table 5-4 Average daily milk production during lactation in Switzerland 1990-2013.

Milk Production Cattle		**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Population Size Mature Dairy Cattle	head	783'100	780'500	763'500	744'450	749'700	739'641	736'043	711'613	701'343	683'545
Lactation Period	day	305	305	305	305	305	305	305	305	305	305
Milk Yield Mature Dairy Cattle	kg/head/day	16.06	16.35	16.39	16.78	16.75	17.09	16.96	17.48	17.97	18.40
Milk Yield Other Mature Cattle	kg/head/day	8.20	8.20	8.20	8.20	8.20	8.20	8.20	8.20	8.20	8.20

Milk Production Cattle		**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Population Size Mature Dairy Cattle	head	669'410	669'410	657'924	638'288	621'008	620'708	618'065	614'795	628'516	599'361
Lactation Period	day	305	305	305	305	305	305	305	305	305	305
Milk Yield Mature Dairy Cattle	kg/head/day	18.75	18.97	19.34	19.77	20.43	20.45	20.57	21.21	21.66	22.27
Milk Yield Other Mature Cattle	kg/head/day	8.20	8.20	8.20	8.20	8.20	8.20	8.20	8.20	8.20	8.20

Milk Production Cattle		**2010**	**2011**	**2012**	**2013**
Population Size Mature Dairy Cattle	head	589'024	589'239	591'212	586'609
Lactation Period	day	305	305	305	305
Milk Yield Mature Dairy Cattle	kg/head/day	22.46	22.63	22.57	22.27
Milk Yield Other Mature Cattle	kg/head/day	8.20	8.20	8.20	8.20

Milk production of mature dairy cattle increased from 4’900 kg per head and year in 1990 (16.06 kg head for 305 days) to 6’792 kg per head and year in 2013 (22.27 kg per head for 305 days; Table 5-4). Statistics of annual milk production are provided by the Swiss Farmers Union (SBV 2014). Milk production includes marketed milk, milk consumed by calves on farms and milk sold outside the commercial industry (MISTA 2014). It should be noted that daily milk yield refers to milk production during lactation (305 days) and not during the whole year (365 days). Accordingly, milk production and energy requirement for lactation was zero during the two remaining months when the cows are dry.

In the year 2003 yearly milk yield surpassed 6000 kg. To achieve yearly milk yields higher than 6000 kg, cows have to be fed with an increasing share of feed concentrates that have a substantially higher net energy (NE) density than the basic feed ration. The model reproduces this behaviour. Due to the increasing ratio of net energy to gross energy the increase of gross energy intake is slower after the year 2003 although milk yield increases more or less at the same rate.

For **other mature cattle** and **growing cattle,** data on energy intake were based on the feeding requirements according to RAP (1999). In the calculation of the NE data, the animal's weight, daily growth rate, daily feed intake (dry matter), daily feed energy intake, and energy required for milk production and pregnancy for the respective sub-categories were considered. The method is described in detail in Soliva (2006). NE is further subdivided into NE for lactation (NEL) and NE for growth (NEV)(Table 5-3). For some of the growing cattle categories NEL is used, rather than NEV that would seem logical. However, cattle-raising is often coupled with dairy cattle activities and therefore the same energy unit (NEL) is used in these cases. Exceptions are the fattening calves (milk-fed calves), whose requirement for energy is expressed as metabolisable energy (ME).

Table 5-5 Gross energy intake per head of different livestock groups. Sub-categories not contained in the CRF-Tables are displayed in italic. Whole time series on a livestock subcategory level are provided in Annex 3 A.3.3.

Gross Energy Intake		**1990-2011**									
		1990	**1995**	**2000**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
		MJ/head/day									
Cattle											
Mature Dairy Cattle		259.3	267.4	280.1	291.6	292.2	295.2	297.2	299.8	300.7	301.4
Other Mature Cattle		205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1
Growing Cattle (weighted average)		93.6	94.3	93.4	90.8	90.9	90.7	90.8	90.4	90.4	90.1
	Fattening Calves	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*
	Pre-Weaned Calves	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*
	Breeding Calves	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*
	Breeding Cattle (4-12 months)	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*
	Breeding Cattle (> 1 year)	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*
	Fattening Calves (0-4 months)	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*
	Fattening Cattle (4-12 months)	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*
Sheep		21.2	24.0	22.4	22.8	22.6	22.2	22.0	22.7	22.6	22.6
Swine		28.3	31.9	28.0	26.6	26.3	26.9	26.7	27.0	27.2	26.9
Buffalo (weighted average)		NA	136.6	146.9	140.6	138.9	130.4	129.1	134.8	136.9	139.8
Camels (weighted average)		NA	NA	34.8	31.7	31.7	31.7	31.6	31.5	31.0	31.4
Deer (weighted average) 1)		50.5	55.3	56.4	55.4	55.8	55.9	56.5	56.8	56.5	56.7
Goats		25.0	27.9	25.7	25.4	25.3	25.0	25.0	25.3	25.1	25.6
Horses (weighted average)		107.3	106.9	107.4	107.7	107.7	107.7	107.7	107.8	107.9	107.9
Mules and Asses (weighted average)		39.2	39.7	39.5	39.4	39.5	39.3	39.2	40.0	40.2	39.9
Poultry 2)		1.5	1.3	1.4	1.2	1.2	1.3	1.3	1.3	1.2	1.2
Rabbits		1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Livestock NCAC (weighted average)		95.6	83.4	37.7	33.3	33.2	32.9	31.7	32.3	32.9	31.7

Gross Energy Intake		**2012-2013**	
		2012	**2013**
		MJ/head/day	
Cattle			
Mature Dairy Cattle		301.2	299.8
Other Mature Cattle		205.1	205.1
Growing Cattle (weighted average)		89.8	89.7
	Fattening Calves	*47.6*	*47.6*
	Pre-Weaned Calves	*55.7*	*55.7*
	Breeding Calves	*26.9*	*26.9*
	Breeding Cattle (4-12 months)	*89.2*	*89.2*
	Breeding Cattle (> 1 year)	*129.1*	*129.1*
	Fattening Calves (0-4 months)	*55.6*	*55.6*
	Fattening Cattle (4-12 months)	*124.6*	*124.6*
Sheep		22.5	22.9
Swine		27.0	28.7
Buffalo (weighted average)		135.9	136.0
Camels (weighted average)		31.6	31.9
Deer (weighted average) 1)		57.0	58.1
Goats		25.7	26.1
Horses (weighted average)		107.9	108.0
Mules and Asses (weighted average)		39.9	39.6
Poultry 2)		1.2	1.2
Rabbits		1.2	1.2
Livestock NCAC (weighted average)		31.0	31.5

1) Deer: Gross energy intake per animal place (mother with offspring)

2) Poultry data is not Gross Energy intake (GE) but Metabolizable Energy intake (ME)

The gross energy intake for other mature cattle is significantly higher than IPCC default values, since the category “other mature cattle” in Switzerland only includes mature cows that produce offspring for meat (so-called “suckler cows” or “mother cows”). Milk production of other mature cattle is 2500 kg per head and year (305 days of lactation) and has not changed over the inventory time period (RAP 1999).

The gross energy intake of growing cattle was calculated separately for all sub-categories displayed in Table 5-5 (in italics) and subsequently averaged (weighted average). The values for all 7 sub-categories are constant over time. Since the composition of the young cattle category changed over time (e.g. more pre-weaned calves, fewer fattening calves, see Table 5-6), the average gross energy intake for young cattle also changes slightly. To calculate an annual emission factor, the categories breeding calves and breeding cattle 4-12 months were combined in the category breeding cattle 1st year (not shown in Table 5-5 and Table 5-6). Accordingly, the respective animals have two separate gross energy intake values, i.e. 26.9 MJ/head/day for the first 4 months and 89.2 MJ/head/day for the last 8 months. The same procedure is applied for fattening calves 0-4 months (55.6 MJ/head/day) and fattening cattle 4-12 months (124.6 MJ/head/day) summing up to the category fattening cattle.

Energy requirements and gross energy intake of **sheep**, **swine**, **goats** and **poultry** were obtained from the respective estimates of the Swiss Farmers Union (SBV 2014, Giuliani 2014). These estimates are not officially published anymore in the statistical yearbooks (e.g. SBV 2014) but are still available from background data and are based on the same method as earlier published energy requirement statistics (e.g. SBV 2007).

Gross energy intake for **horses**, **mules and asses** were estimated by Stricker (2012), mainly based on Meyer and Coenen (2002).

For **buffalo**, **camels** and **deer**, energy intake was derived from data on dry matter intake provided in Flisch et al. (2009).

Energy intake of **rabbits** was estimated by Menzi (2014) based on Schlegel and Menzi (2013).

Finally for **Livestock NCAC** the same energy intakes as the respective animal categories in the official census were used.

Final compilation of livestock gross energy intake was conducted in Agroscope (2015). Resulting estimates are provided in Table 5-5 (main categories) and in Annex 3 A3.3 (all years and all sub-categories).

Methane conversion rate (Y_m)

For the methane conversion rate (Y_m), few country-specific data exist. For **cattle**, **sheep** and **buffalo** default values recommended by the IPCC for developed countries in Western Europe were mainly used (IPCC 2006: Table 10.12, 10.13, 10A.2, 10A.3). Due to the great importance of mature dairy cattle, a country-specific Y_m was derived from a series of measurements conducted under Swiss specific feeding and husbandry conditions at the Federal Institute of Technology in Zürich. The value of 6.9% is based on data compiled in Zeitz et al. (2012) and additional measurements described in Estermann et al. (2001), Külling et al. (2002) and Staerfl et al. (2012). For all juvenile cattle consuming only milk (i.e. fattening calves) the methane conversion rate is assumed to be zero.

According to table 10.13 in IPCC (2006) two different Y_m were used for **sheep**, namely 4.5 % for lambs < 1 year and 6.5 % for mature sheep. Overall Y_m was subsequently weighted according to the population structure. For **camels** and **deers** the same overall methane conversion rate as for sheep was applied, assuming the same relationship between adult and juvenile animals.

For **Swine** a rather low methane conversion rate of 0.6% was used. This value has been suggested by Crutzen et al. (1986) and was confirmed by the compilation of references in

Minonzio et al. (1998). Since the 2006 IPCC Guidelines do not provide a default value for **goats**, an Y_m of 6% was adopted based on the work of Martínez-Fernández et al. (2014) and Fernández et al. (2013). For **Horses**, **mules and asses** an Y_m of 2.45% was used, which corresponds to a methane energy loss of 3.5% of digestible energy (Vermorel et al. 1997, Minonzio et al. 1998) and a feed digestibility of 70% (Stricker 2012). For **poultry** a country-specific value (0.16% of metabolisable energy) was used. This value was evaluated in an in vivo trial with broilers (Hadorn and Wenk 1996). For **rabbits** an Y_m of 0.6% was applied as suggested in the national greenhouse gas inventory of Italy (ISPRA 2014). Finally, as for gross energy intake, the same methane conversion rates as the respective animals in the official census were used for **livestock NCAC**.

5.2.2.3 Activity Data

Livestock population data were obtained from statistics published by the Swiss Farmers Union (SBV 2014) and the Swiss Federal Statistical Office (SFSO 2014d)(Table 5-6). All activity data were revised and harmonized during a joint effort of the Agroscope Reckenholz-Tänikon Research Station (ART) and the Swiss College of Agriculture (SHL) in 2011 (ART/SHL 2012).

The category other mature cattle only includes mature cows used to produce offspring for meat.

Emission estimation for growing cattle was conducted at a more disaggregated level than the one displayed in the CRF tables. The CRF livestock category growing cattle includes the sub-categories fattening calves, pre-weaned calves, breeding calves, breeding cattle 4-12 months, breeding cattle > 1 year, fattening calves 0-4 months and fattening cattle 4-12 months. Although not young cattle in the proper sense, bulls are contained in the categories breeding cattle (> 1 year) and fattening cattle (4-12 months) according to their purposes. This disaggregation of the cattle category enhances the accuracy of the emission estimation procedure from livestock activities (also refer to chapter 5.3.2.1).

Emission estimation for buffalo, camels, horses, mules and asses and deers was also conducted on a more disaggregated level than displayed in the CRF. Additional data on a livestock sub-category level are contained in Annex 3 A3.3.

Additionally to official statistical data, population data of livestock not covered by the agricultural census of the Swiss Federal Statistical Office were assessed. The respective category “Livestock NCAC” (livestock not covered by agricultural census) consists of sheep, goats, horses and mules and asses held for non-agricultural purposes (e.g. horses for sports and leisure) and/or livestock held by private persons or enterprises that do not fulfil the criteria of an agricultural enterprise. Data for the respective horses, mules and asses were derived from Poncet et al. (2007) and Poncet et al. (2009). For sheep and goats, data from individual cantons having full livestock censuses were used to estimate the relative share for the whole of Switzerland. The respective estimates were conducted in the course of the elaboration of the gross nutrient balance of the Swiss Federal Statistical Office (SFSO 2014).

Table 5-6 Activity data for calculating methane emissions from Enteric fermentation (ART/SHL 2012, SBV 2014, SFSO 2014d, SFSO 2014e). The complete time series by livestock subcategory level are provided in Annex 3 A3.3.

Population Size		**1990-2011**									
		1990	**1995**	**2000**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
		1'000 head									
Cattle		1'855	1'748	1'588	1'555	1'567	1'572	1'604	1'597	1'591	1'577
Mature Dairy Cattle		783	740	669	621	618	615	629	599	589	589
Other Mature Cattle		12	23	45	78	87	94	98	108	111	111
Growing Cattle		1'060	986	874	856	862	863	877	890	891	877
	Fattening Calves	*112*	*102*	*103*	*106*	*101*	*100*	*95*	*101*	*99*	*101*
	Pre-Weaned Calves	*10*	*18*	*36*	*62*	*67*	*72*	*76*	*86*	*88*	*88*
	Breeding Cattle 1st Year										
	Breeding Calves	*214*	*166*	*76*	*75*	*77*	*76*	*80*	*77*	*77*	*75*
	Breeding Cattle (4-12 months)	*132*	*129*	*161*	*147*	*147*	*147*	*152*	*149*	*149*	*145*
	Breeding Cattle (> 1 year)										
	Breeding Cattle 2nd Year	*253*	*239*	*222*	*205*	*210*	*210*	*213*	*212*	*213*	*207*
	Breeding Cattle 3rd Year	*151*	*139*	*130*	*113*	*110*	*109*	*110*	*119*	*119*	*116*
	Fattening Cattle										
	Fattening Calves (0-4 months)	*88*	*82*	*43*	*35*	*35*	*34*	*36*	*35*	*34*	*34*
	Fattening Cattle (4-12 months)	*100*	*110*	*105*	*112*	*114*	*114*	*116*	*112*	*111*	*111*
Sheep		395	387	421	446	448	444	446	432	434	424
Swine		1'787	1'446	1'498	1'609	1'635	1'573	1'540	1'557	1'589	1'579
Buffalo		0	0	0	0	0	0	0	1	1	1
Camels		0	0	1	3	3	4	4	5	6	6
Deer [1)]		0	1	3	4	4	4	5	5	6	6
Goats		68	53	62	74	76	79	81	81	83	83
Horses		28	41	50	55	56	58	59	60	62	57
Mules and Asses		6	8	12	16	16	17	18	19	20	19
Poultry		5'938	6'251	6'983	8'260	7'670	8'228	8'543	8'809	9'025	9'478
Rabbits		61	41	28	25	24	27	25	28	35	34
Livestock NCAC		28	30	94	86	82	80	86	87	85	90

Population Size		**2012-2013**	
		2012	**2013**
		1'000 head	
Cattle		1'565	1'557
Mature Dairy Cattle		591	587
Other Mature Cattle		114	117
Growing Cattle		859	854
	Fattening Calves	*99*	*97*
	Pre-Weaned Calves	*91*	*93*
	Breeding Cattle 1st Year		
	Breeding Calves	*73*	*72*
	Breeding Cattle (4-12 months)	*140*	*138*
	Breeding Cattle (> 1 year)		
	Breeding Cattle 2nd Year	*200*	*198*
	Breeding Cattle 3rd Year	*112*	*111*
	Fattening Cattle		
	Fattening Calves (0-4 months)	*34*	*34*
	Fattening Cattle (4-12 months)	*112*	*111*
Sheep		417	409
Swine		1'544	1'485
Buffalo		1	0
Camels		6	6
Deer [1)]		6	6
Goats		85	85
Horses		58	57
Mules and Asses		20	20
Poultry		9'955	10'079
Rabbits		28	28
Livestock NCAC		99	95

1) Deer: numbers correspond to animal places i.e. mother with offspring.

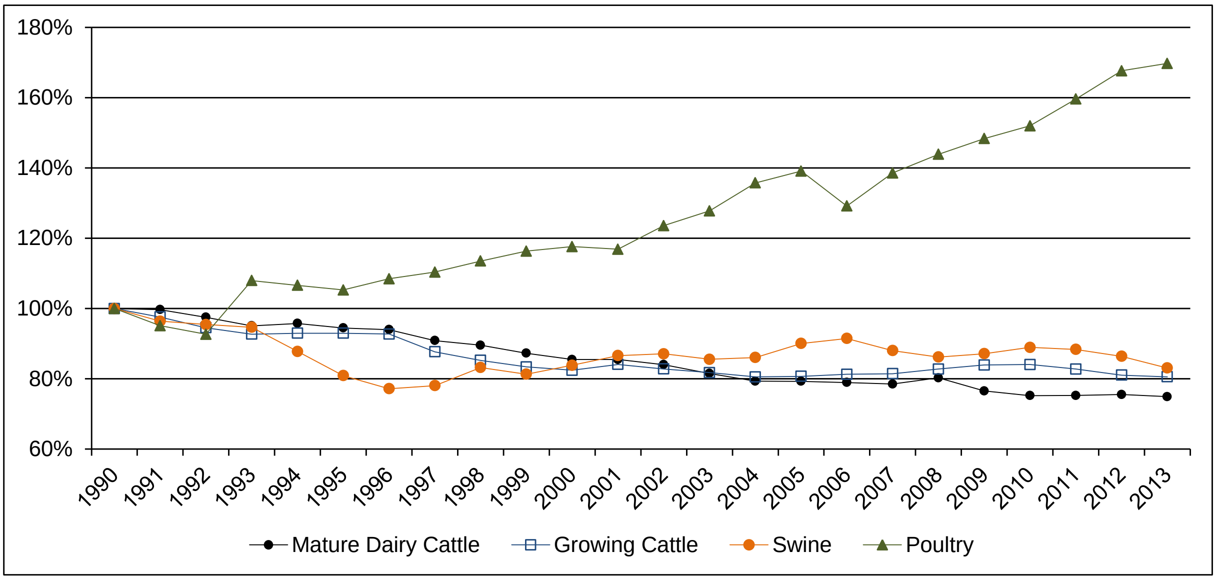


Figure 5-5 Relative development of main animal categories 1990-2013. The category with the strongest increase, i.e. other mature cattle, is not displayed, as it increases to over 970% of the 1990 value by 2013.

Livestock populations in Switzerland are primarily influenced by the general agricultural policy, i.e. the subsidy system, the milk quotation system and the development of the economic framework conditions. The number of cattle declined slightly until the year 2004. However, cattle livestock numbers increased slightly between 2004 and 2008, mainly due to an increase of the number of young cattle. Since 2008 the cattle population has been decreasing again, possibly due to the suspension of the milk quotation in 2009.

After a decrease until 1996, the number of swine increased until 2006 – a process that has been observed in many other European countries (SBV 2004: p.69). Since then, the number of swine has fluctuated slightly below the level of 2006. The number of poultry shows a rapid increase between 1990 and 2013 with a distinct dip only between 2005 and 2006, a consequence of changed human consumption patterns as a result of the avian flu in 2006.

The number of sheep has been more or less constant while the number of goats has increased following a decline between 1990 and 1995.

5.2.3 Uncertainties and Time-Series Consistency

For the uncertainty analysis the input data from ART (2008a) were used and were updated with current activity and emission data as well as with new default uncertainties of the 2006 IPCC Guidelines. The arithmetic mean of the lower and upper bound uncertainty was used for activity data (6.4%) and for emission factors (16.9%), resulting in a combined uncertainty of 18.1% for Approach 1 analysis.

For the Approach 2 analysis, asymmetric probability distributions as well as possible correlations of input data were considered. The uncertainty interval of the Approach 2 analysis lies between -18% and +18% (Annex 2, Table A-8).

For further uncertainty-results also consult chapter 1.7.1 and Annex 2.

The time series 1990–2013 are consistent, although the following issues should be considered:

- Gross energy intake of some of the aggregated animal categories reveal some fluctuations during the inventory period due to varying shares of the sub-categories.
- Gross energy intake as well as the implied emission factor for mature dairy cattle increase, mainly as a result of higher milk production (Table 5-4).
- Between 1998 and 1999 the questionnaire for the collection of livestock data was modified. In some animal categories this led to minor ruptures in the time series. Consequences for overall emissions are, however, of minor importance. An analysis conducted in 2012 revealed, that while the average annual change for the years 1990–2011 over all animal categories (excluding other mature cattle) was 3.3% points, the annual change for the years 1998-1999 was 3.8% points (ART/SHL 2012).
- For the last five inventory years the population statistics of growing cattle were not available in the usual format. Data for 2009 to 2013 is based on the animal traffic database. Aggregation was adapted to the format necessary for the AGRAMMON-model and the GHG Inventory by the Swiss College of Agriculture SHL (SHL 2010). Data in the animal traffic database are considered more complete than the data from the survey of the SFSO because the latter includes also animals held outside agricultural enterprises.

5.2.4 Source-Specific QA/QC and Verification

General QA/QC measures are described in NIR chapter 1.2.3.

Since the CRF reporter was not available at the time of updating the EMIS data-base, the emission rates from the EMIS data-base were compared to data from last CRF submission tables (2014) for plausibility reasons.

All further category-specific QA/QC activities are described in a separate document (ART 2013a). General information on agricultural structures and policies is provided and eventual differences between national and (IPCC) standard values are being analysed and discussed. Furthermore, comparisons with data from other countries were conducted and discussed where possible. ART 2013a is continuously updated with the most recent inventory data.

Livestock data were compared with the livestock data provided by the FAO and checked for plausibility. In all cases the new recalculated data according to ART/SHL (2012) are considered more reliable than the FAO data. Small inconsistencies (usually in the order of ± 2%) are due to updates of provisional data that are not considered by the FAO. For horses, mules and asses disagreements might be due to the different accounting of agricultural and non-agricultural horses. The Swiss inventory system accounts for all animals and splits the population into animals captured by the official agricultural census and livestock not covered by agricultural census. Moreover, the numbers of mules and asses is higher in the Swiss GHG-Inventory because unlike the FAO, Switzerland accounts also for ponies and lesser horses. The total numbers of poultry in the GHG-Inventory and the FAO data also show minor discrepancies due to different accounting of turkeys, geese, ducks and quails.

Seasonal fluctuation of the cattle population was analysed for the years 2005-2007 based on detailed information from the Swiss Farmers Union (SBV 2007a). Seasonal fluctuations are usually in the order of ±3% with census data (April) always slightly above the annual mean.

Data from the animal traffic database (i.e. cattle populations for the years 2009-2013) refer to annual mean populations.

Total NE-intake of the cattle population as calculated in the Swiss GHG-Inventory is in accordance with an independent calculation from the Swiss farmers union (SBV 2007). In a check during the submission 2010 the average absolute difference for the time period 1990-2004 was ±1.2%.

IPCC tables with data for estimating emission factors for cattle (such as weight, weight gain, milk production) were filled in, checked for consistency and confidence and compared with IPCC default values (refer to Annex 3 A3.3). Methane conversion rates (Y_m) and values of feed digestibility were compared to literature values representative for Swiss conditions.

During the years 2009-2012 the animal nutrition group of the Swiss Federal Institute of Technology in Zürich investigated the effect of different feeding and management strategies on methane and nitrous oxide emissions from Enteric fermentation and Manure management of cattle, held under typical Swiss management conditions (Kreuzer 2012). Measured values of various parameters such as Y_m or feed digestibility were compared to IPCC default values and values in the Swiss greenhouse gas inventory (Zeitz et al. 2012). In the case of mature dairy cattle the data basis was considered sufficient to adopt a country-specific methane conversion rate that is considerably higher than IPCC default.

During the past years a couple of studies have been conducted to verify methane emissions at the regional scale, comparing bottom-up estimates with atmospheric measurements. While Hiller et al. (2014a) found that methane emissions could be underestimated by the inventory method, Stieger (2014) reported a very good accordance of bottom-up estimates and flux measurements. It should be noted though, that agricultural methane emission estimates have been since revised and lie approximately 10% above the estimates used in these studies. Furthermore, the methodological approaches of atmospheric measurements as conducted by Hiller et al. (2014a) still rely on a number of rather uncertain basic assumptions and are therefore not beyond doubts. Additionally, it has been stated, that the differences between bottom-up and top-down estimates are possibly due to the limitations of the geographical emission allocation within the spatial explicit inventory (Hiller et al. 2014).

5.2.5 Source-Specific Recalculations

Several new livestock categories are reported for the first time in the 2015 submission (buffalo, camels, deer, rabbits, livestock NCAC). On average, the respective emissions sum up to 0.45% of total methane emissions from Enteric fermentation (14.9 kt CO_2 equivalents).

Gross energy intake of mature dairy cattle was recalculated with a new more detailed model. For the years 1990-2003 changes are negligible. However, for the years 2004-2012 gross energy intake is increasingly lower than predicted by the old model for reasons explained in chapter 5.2.2.2.

Milk yield of mature dairy cattle in the year 2012 was slightly revised due to an update of the provisional value of the Swiss Farmers Union.

Preliminary estimates for energy requirements for sheep, swine, goats and poultry for the years 2010-2012 were revised due to an updated dataset received from the Swiss Farmers

Union (Giuliani 2014). The effect of the recalculation on overall greenhouse gas emissions is negligible.

All methane conversion rates were revised in the course of the switch to the 2006 IPCC Guidelines.

General information on recalculations is provided in chapter 10.

5.2.6 Source-Specific Planned Improvements

Planned improvements for future submissions are the further development, adaptation and verification of the dairy cow feeding model (GE, Y_m).

Furthermore, further QA/QC checks of the new methodologies will be conducted and the respective documentation shall be updated.

5.3 Source Category 3B – Manure Management

5.3.1 Source Category Description

Approach 1 Key Category 3B

CH_4 emissions from Manure management (level and trend)
Indirect N_2O emissions from Manure management (level)

Approach 2 Key Category 3B

CH_4 emissions from Manure management (level and trend)
Indirect N_2O emissions from Manure management (level and trend)

The emission source is the domestic livestock population broken down into 3 cattle categories (mature dairy cattle, other mature cattle, growing cattle), sheep, swine, buffalo, camels, deer, goats, horses, mules and asses, poultry, rabbits and livestock not covered by agricultural census (Livestock NCAC)(Table 5-7). Six (CH_4) respectively five (N_2O) different manure management systems are considered as well as indirect N_2O emissions from Manure management (Table 5-8) CH_4 and N_2O emissions from Manure management are reported. The total emissions from Manure management closely follow the development of the cattle population. Emissions declined from 1990 until 2004, increased until 2008 and subsequently decreased again. Significant contributors to CH_4 emissions from Manure management are cattle with approximatively 74% and swine with approximatively 23%. Likewise, cattle and swine contribute significantly to N_2O emissions with 70% and 16% respectively.

Table 5-7 Specification of source category 3B Manure management by livestock categories. (AD: Activity data; EF: Emission factor).

3B	Source	Specification	Data Source
3B1	Cattle	Mature Dairy Cattle Other Mature Cattle Growing Cattle (Fattening Calves, Pre-Weaned Calves, Breeding Cattle 1st year (Breeding Calves + Breeding Cattle 4-12 months), Breeding Cattle > 1 year (Breeding Cattle 2nd year + Breeding Cattle 3rd year), Fattening Cattle (Fattening Calves 0-4 months + Fattening Cattle 4-12 months))	AD: SBV 2014, ART/SHL 2012, SFSO 2014d EF: Soliva 2006, Agroscope 2014c; RAP 1999, Kupper et al. 2013, IPCC 2006
3B2 3B3 3B4d	Sheep Swine Goats	Lambs < 1 year Mature Sheep Fattening Sheep Milk Sheep Piglets Fattening Pig over 25 kg Dry Sows Nursing Sows Boars Goat Places	AD: SBV 2014, ART/SHL 2012, SFSO 2014d EF: IPCC 2006, Kupper et al. 2013, IPCC 2006
3A4a 3A4b 3A4c	Buffalo Camels Deer	Bisons < 3 years Bisons > 3 years Llamas < 2 years Llamas > 2 years Alpacas < 2 years Alpacas > 2 years Fallow Deer Red Deer	AD: SBV 2014, SFSO 2014d EF: Flisch et al. 2009, Kupper et al. 2013, IPCC 2006
3A4e 3A4f	Horses Mules and Asses	Horses < 3 years Horses > 3 years Mules Asses	AD: SBV 2014, ART/SHL 2012, SFSO 2014d EF: Stricker 2012, Kupper et al. 2013, IPCC 1997a, IPCC 2006
3A4g	Poultry	Growers Layers Broilers Turkey Other Poultry	AD: SBV 2014, ART/SHL 2012, SFSO 2014d EF: Kupper et al. 2013, IPCC 2006
3A4h i	Rabbits		AD: SBV 2014, SFSO 2014d EF: IPCC 2006
3A4h ii	Livestock NCAC	Sheep Goats Horses < 3 years Horses > 3 years Mules Asses	AD: SFSO 2014e EF: see above

Table 5-8 Specification of source category 3B Manure management by manure management systems. (AD: Activity data; EF: Emission factor).

3B	Source	Specification	Data Source
3B6a	Direct Emissions	Liquid systems	MS: Kupper et al. 2013 MCF: Mangino et al. 2001 EF_3: IPCC 2006, Kupper et al. 2013
3B6b		Solid storage and dry lot	MS: Kupper et al. 2013 MCF: IPCC 2006 EF_3: IPCC 2006
3B6c		Digesters (Anaerobic digestion)	MS: Kupper et al. 2013, SFOE 2014a, Genossenschaft Ökostrom Schweiz 2014, GES Biogas GmbH 2014, Koehli L. 2014 MCF: IPCC 2006, Mangino et al. 2001, UNFCCC 2013c EF_3: IPCC 2006
3B6d		Other (Deep litter, Poultry manure)	MS: Kupper et al. 2013 MCF: IPCC 2006 EF_3: IPCC 2006
3B5a	Indirect Emissions	Atmospherical deposition	$Frac_{GasMS}$: Kupper et al. 2013, EMEP/EEA 2013 EF_4: Bühlmann 2014, Bühlmann et al. 2015
3B5b		Leaching and run-off	NO

5.3.2 Methodological Issues

5.3.2.1 Methodology

The calculation is based on methods described in the 2006 IPCC Guidelines (CH_4: IPCC 2006 equation 10.23; N_2O: IPCC 2006 equation 10.25).

CH_4 emissions from Manure management were generally estimated using Tier 2 methodology. For cattle a more detailed method was applied, estimating volatile solids (VS) excretion based on gross energy intake estimates as used for Enteric fermentation. Methane conversion factors (MCF) are from IPCC (2006; solid storage, pasture range and paddock, anaerobic digesters, poultry manure) or were modelled according to Mangino et al. (2001).

N_2O emissions from Manure management were estimated using a Tier 2 methodology. Activity data were adjusted to the particular situation of Switzerland in coordination with the Swiss ammonia model AGRAMMON (Kupper et al. 2013). Detailed country-specific data on nitrogen excretion rates, manure management system distribution and nitrogen volatilisation were applied. Emission factors for direct N_2O emissions (EF_3) were based on IPCC (2006) whereas the emission factor for indirect emissions from atmospheric deposition was based on Bühlmann et al. (2015) and Bühlmann (2014). Leaching of NO_3^- from manure management systems was considered negligible and is thus not included in the estimates. Note that N_2O emissions from pasture, range and paddock are reported under 3D Agricultural soils, source category 3Da3 (Urine and dung deposited by grazing animals).

For calculation of CH_4 and N_2O emissions, slightly different livestock sub-categories were used (Table 5-9). The livestock categories reported in the CRF-tables are the same, but the respective sub-categories as a basis for the calculation are different. The categorization for the estimation of CH_4 emissions had to be adapted to data availability for energy requirements, while the categorisation for the estimation of N_2O emissions is determined by the respective categorisation of the Swiss ammonia inventory (AGRAMMON, Kupper et al. 2013, Flisch et al. 2009). Nevertheless, there is no inconsistency in the total number of animals as they are the same both for CH_4 and N_2O emissions. Note that although not growing cattle in the proper sense, bulls are contained in the categories breeding cattle > 1 year, breeding cattle 3rd year and/or fattening cattle according to their purposes.

The calculation of CH_4 and N_2O emissions is conducted in Agroscope (2015).

Table 5-9 Livestock categories for estimating CH_4 and N_2O emissions from Manure management.

3B	**CH_4**		**N_2O**	
Cattle	Mature Dairy Cattle		Mature Dairy Cattle	
	Other Mature Cattle		Other Mature Cattle	
	Growing Cattle	Fattening Calves Pre-Weaned Calves Breeding Cattle 1^{st} year (Breeding Calves + Breeding Cattle 4-12 months) Breeding Cattle > 1 year Fattening Cattle (Fattening Calves 0-4 months + Fattening Cattle 4-12 months)	Growing Cattle	Fattening Calves Pre-Weaned Calves Breeding Cattle 1^{st} year Breeding Cattle 2^{nd} year Breeding Cattle 3^{rd} year Fattening Cattle
Sheep	Lambs < 1 year Mature Sheep		Fattening Sheep Milk Sheep	
Swine	Swine		Piglets Fattening Pig over 25 kg Dry Sows Nursing Sows Boars	
Buffalo	Bisons < 3 years Bisons > 3 years		Bisons < 3 years Bisons > 3 years	
Camels	Llamas < 2 years Llamas > 2 years Alpacas < 2 years Alpacas > 2 years		Llamas < 2 years Llamas > 2 years Alpacas < 2 years Alpacas > 2 years	
Deer	Fallow Deer Red Deer		Fallow Deer Red Deer	
Goats	Goats		Goat places	
Horses	Horses < 3 years Horses > 3 years		Horses < 3 years Horses > 3 years	
Mules and Asses	Mules Asses		Mules Asses	
Poultry	Poultry		Growers Layers Broilers Turkey Other Poultry	
Rabbits	Rabbits		Rabbits	
Livestock NCAC	Sheep Goats Horses < 3 years Horses > 3 years Mules Asses		Sheep Goats Horses < 3 years Horses > 3 years Mules Asses	

5.3.2.2 Emission Factors CH_4

Calculation of CH_4 emissions from Manure management was based on methods described in the 2006 IPCC Guidelines (IPCC 2006, equation 10.23):

$$EF_T = VS_T \bullet 365\,days/year \bullet B_{0T} \bullet 0.67\,kg/m^3 \bullet \sum_S MCF_S \bullet MS_{TS}$$

EF_T = annual CH_4 emission factor for livestock category T (kg/head/year)

VS_T = daily volatile solids (VS) excreted for livestock category T (kg/head/day)

B_{0T} = maximum CH_4 producing capacity for manure produced by livestock category T (m^3/kg)

0.67 kg/m^3 = conversion factor of m^3 CH_4 to kilograms CH_4

MCF_S = CH_4 conversion factors for each manure management system *S* (%)

MS_{TS} = fraction of livestock category *T*'s manure handled using manure management system *S* (dimensionless)

Volatile solids excretion (VS)

The daily excretions of volatile solids (VS) for **all cattle sub-categories** were estimated according to equation 10.24 in the 2006 IPCC Guidelines (IPCC 2006):

$$VS = \left[GE \bullet \left(1 - \frac{DE\%}{100} \right) + (UE \bullet GE) \right] \bullet \left[\frac{1 - ASH}{EDF} \right]$$

VS = volatile solids excretion per day on a dry-organic matter basis (kg/day)

GE = gross energy intake (MJ/head/day)

DE = digestibility of the feed (%)

(UE • GE) = urinary energy expressed as fraction of GE

ASH = ash content of manure calculated as a fraction of the dry matter feed intake

EDF = energy density of feed, conversion factor for dietary GE per kg of dry matter (MJ/kg)

Gross energy intake was calculated according to the method described in Chapter 5.2.2.2. In the case of **mature dairy cattle** the same model was used as for the estimation of CH_4 emissions from Enteric fermentation. Content of net energy, gross energy and ash in feed dry matter as well as feed digestibility were also estimated using the Agroscope feeding model (Agroscope 2014c). The digestibility of feed is of crucial importance for the calculation of volatile solids. The modelled values for dairy cows are somewhat higher than the IPCC default and were compared to measurements from feeding trials in Switzerland. The comparison revealed that modelled values are on average slightly higher than measurements. Accordingly, an adjustment was made in order to take account of the high feeding level that is usually above maintenance (Ramin and Huhtanen 2012). High feeding levels may lead to an increase in rumen passage rate and subsequently to lower feed digestibility (Nousiainen et al. 2009). The correction decreased the feed digestibility on average by 2.5 per cent points. Resulting feed digestibility was 72.2% on average, gross energy content (EDF) was 18.26 MJ/kg and ash content was 9.0% each with very small fluctuations along the time series. Urinary energy expressed as fraction of gross energy was 0.04 (IPCC 2006).

IPCC default values of 65% respectively 60% were taken for the feed digestibility of **calves and other growing cattle**. For the urinary energy expressed as fraction of gross energy and for the energy density of the feed (EDF) the IPCC default values, i.e. 0.04 and 18.45 MJ/kg were adopted. Furthermore, an ash content of 8.0% was used for all these categories.

For VS excretion of the livestock categories **sheep**, **swine**, **goats**, **mules and asses**, **poultry**, **rabbits** and **livestock NCAC**, default values from IPCC were taken (IPCC 2006, Tables 10A-7, 10A-8, 10A-9). Considering the gross energy intake of horses, the value in the revised 1996 IPCC Guidelines (1.72 kg/head/day) is clearly more appropriate and was thus adopted instead of the default value of the 2006 Guidelines (i.e. 2.13 kg/head/day).

For **buffalo**, **camels** and **deer** VS excretion was again estimated using equation 10.24 with default values for feed digestibility and ash content (IPCC 2006). Feed digestibility was 55% for buffalos and 60% for camels and deer (assuming similar feed composition as for sheep). The urinary energy as fraction of the gross energy was 0.04, the energy density of the feed (EDF) was 18.45 MJ/kg and the ash content of manure was 8.0% (IPCC 2006).

Maximum CH_4 producing capacity (B_0)

For the methane producing capacity (B_o) default values were used (IPCC 2006). As for deer, no default value was available and the same value as for sheep was therefore applied i.e. 0.19 m^3/kg.

Methane conversion factor (MCF)

For estimating CH_4 emissions from Manure management, six different manure management systems are distinguished. Switzerland has an average annual temperature below 15°C (MeteoSwiss 2014) and was therefore allocated to the cool climate region without differentiation.

In the case of **solid manure** and **pasture range and paddock** the default MCF values from table 10.17 of the 2006 IPCC Guidelines were used (Table 5-10).

Liquid/slurry systems are usually responsible for the major part of methane emissions from Manure management. Accordingly a more detailed model was used to determine the respective MCF. For this purpose the model developed by Mangino et al. (2001) that is also used to derive the 2006 IPCC default values was adapted to the specific conditions of Switzerland. On a monthly time step, loading of a virtual liquid/slurry manure system was simulated according to the VS excretion of the total livestock herd and the manure management system distribution (MS) in the respective inventory year. Thereby it was assumed that excretion on pasture, range and paddock takes only place during summer months, i.e. from April to September. Subsequently, monthly manure degradation was forecast using the temperature-dependent van’t Hoff-Arrhenius equation with the parametrization as suggested by Mangino et al. (2001). Monthly mean air temperatures for the Swiss central plateau during the 1981-2010 time period were obtained from the Federal Office of Meteorology and Climatology (MeteoSwiss 2014). Minimum temperature in the liquid/slurry system was allowed to drop to 1°C instead of 5°C as proposed in the original model (see e.g. Vergé et al. 2007, Van der Zaag et al. 2013). Any carry-over effect of undegraded manure from one month to the next was neglected (see e.g. Park et al. 2006, Van der Zaag et al. 2013). Finally, an annual methane conversion factor was calculated by dividing the total VS degraded by the total load of VS.

Several authors have found that the simulated MCF-values according to the model described above are unrealistically high (Park et al. 2006, Van der Zaag et al. 2013). Consequently they propose to use a management and design factor (MDP factor) to bring the modelled factors into accordance with measurements. Accordingly a MDP factor of 0.8 was applied here as suggested by Mangino et al. (2001). The resulting MCF-values for liquid/slurry systems range from 13.5% to 14.5%. The variation of the MCF along the time series is due to varying shares of manure dropped on pasture, range and paddock (as livestock is only grazing during summer, the relative share of low methane conversion factors during the cold winter month increases when summer grazing time increases). The higher the share of manure dropped on pasture, range and paddock, the lower is the overall MCF.

Anaerobic digestion of animal manure is increasing in Switzerland since the 1990s but is still not widespread (3.1% of all animal manure in 2013). Emissions from the digestion plant itself are reported under source category 5B2 (Anaerobic digestion at biogas facilities) and described in chapter 7.3. However, emissions from manure storage before alimentation into the digester are reported under agriculture. The amount of manure digested anaerobically was estimated based on total energy production (SFOE 2014a) and eight monitoring protocols of agricultural biogas plants (Genossenschaft Ökostrom Schweiz 2014, GES Biogas GmbH 2014). According to the data in the monitoring protocols the total amount of manure entering the plant originated from cattle manure stored as liquid/slurry (57%) and solid storage (23%) and from swine manure stored as liquid/slurry (20%). It is assumed that 22.5% of the liquid/slurry manure is coming from the farm where the biogas plant is located and is hence directly fed into the digester on a daily basis (Koehli 2014). The respective MCF was thus set to zero. As solid manure usually has a low MCF and is stored for only a short period before being fed into the digester, the respective MCF was also set to zero. The MCF for the remaining liquid/slurry manure that is delivered from neighbouring farms to the biogas plant was estimated with the methodology described in the "Standard method for compensating projects of the type "agricultural biogas plants"" (FOEN 2014n). This method is based on the "Approved small scale baseline and monitoring methodology AMS-III.D./Version 19.0. Methane recovery in animal manure management systems" and relies thus on a generally accepted foundation (UNFCCC 2013c). Accordingly the MCF value for conventional liquid/slurry systems given in Table 5-10 is reduced according to the duration of pre-storage before the manure is delivered to the digester. The average pre-storage time was estimated to be 12 days (Koehli 2014). The resulting weighted average MCF-value for anaerobic digestion varies between 2.6% and 2.8%. Variation is due to the variation of the underlying MCF of liquid/slurry systems.

Fattening calves, sheep, camels, deer and goats are kept in **deep litter systems**. A MCF of 10% was adopted, which is the mean value between the IPCC default values for cattle and swine deep bedding < 1 month and > 1 month at 10 °C (IPCC 2006). The choice of a MCF of 10% for deep litter is supported by the specific feeding and manure management regime in Switzerland (especially cold winter temperatures) and confirmed by a number of studies representative for the country-specific management conditions (Amon et al. 2001, Külling et al. 2002, Külling et al. 2003, Moller et al. 2004, Hindrichsen et al. 2006, Park et al. 2006 and Sommer et al. 2007, Zeitz et al. 2012). For further details see FOEN 2011 (16.5 attachment E).

For all poultry categories a MCF value of 1.5% was used according to the default value for **poultry manure systems** in the 2006 IPCC Guidelines.

Table 5-10 Manure management systems and methane conversion factors (MCFs). Blue: annually changing parameters, value for 2013.

Manure management system		Description	MCF (%)
Pasture		Manure is allowed to lie as it is, and is not managed (distributed, etc.).	1.0
Solid storage		Dung and urine are excreted in a barn. The solids (with and without litter) are collected and stored in bulk for a long time (months) before disposal.	2.0
Liquid/slurry		Combined storage of dung and urine under animal confinements for longer than 1 month.	13.7
Digesters		Storage before alimentation into anaerobic digester. Storage system can be liquid/slurry or solid storage.	2.6
Other	Deep litter	Dung and urine is excreted in a barn with lots of litter and is not removed for a long time (months).	10.0
	Poultry system	Manure is excreted on the floor with or without bedding.	1.5

Manure management system distribution (MS)

The fraction of animal manure handled using different manure management systems (MS) as well as the percentages of urine and dung deposited on pasture, range and paddock was separately assessed for each livestock category (Table 5-11). The fractions are determined by the livestock husbandry system (e.g. tie stall or loose housing system) as defined in Flisch et al. (2009). Estimation is conducted within the Swiss ammonium model AGRAMMON (Kupper et al. 2013) based on expert judgement and values from the literature (1990, 1995) and on extensive farm surveys (2002, 2007, 2010). The data clearly reproduce the shift towards an increased use of pasture, range and paddocks and a decrease in solid storage. The changes of the manure management system distribution reflect the shift to a more animal-friendly livestock husbandry in the course of the agricultural policy reforms during the 1990s and the early 20th century. One of the most important voluntary programs in this context is called “RAUS” and implies at least 156 days of pasture per year (Schweizerischer Bundesrat, 2008). Accordingly, the share of mature dairy cows (and other animals) going to pastures increased substantially and the length of stay on the pasture increased by 50%. In the year 2007 78% of the dairy cows were held on farms participating in the RAUS program. The average number of pasture days (including all farms) in that year was 181, and it was 177 in 2010. It can thus be assumed, that already in the early years of the new millennium most farms accomplished the transition to RAUS and that a new management standard was reached at this point of time, which did not change significantly afterwards.

5.3.2.3 Activity Data CH_4

Activity data of all livestock categories covered by the official census were obtained from SBV (2014) and the SFSO (2014d). The respective data were revised and harmonized during a joint effort of the Agroscope Reckenholz Tänikon Research Station (ART) and the Swiss College of Agriculture (SHL) in 2011 (ART/SHL 2012). Additionally to official statistical data, population data of livestock not covered by the agricultural census of the Swiss Federal Statistical Office was assessed (Poncet et al. 2007, Poncet et al. 2009, SFSO 2014e). For further details and additional data on a livestock sub-category level refer to chapter 5.2.2.3, Table 5-6 as well as Annex 3 A3.3.

Table 5-11 Manure management system distribution (MS) according to the AGRAMMON model. Detailed data on livestock subcategory levels are provided in Annex 3 A3.3.

MS Distribution	1990					1995					2002				
	%					%					%				
	Liquid / Slurry	Solid storage	Pasture range and paddock	Digesters	Other (Deep litter, Poultry manure)	Liquid / Slurry	Solid storage	Pasture range and paddock	Digesters	Other (Deep litter, Poultry manure)	Liquid / Slurry	Solid storage	Pasture range and paddock	Digesters	Other (Deep litter, Poultry manure)
Mature Dairy Cattle	63.7	27.6	8.3	0.4	0.0	65.7	24.4	9.5	0.4	0.0	65.3	16.2	18.0	0.5	0.0
Other Mature Cattle	41.2	32.1	26.3	0.4	0.0	39.3	34.1	26.2	0.4	0.0	39.7	20.7	39.1	0.5	0.0
Growing Cattle (weighted average)	47.5	31.7	15.8	0.4	4.5	48.4	30.9	15.9	0.4	4.5	42.1	25.4	27.5	0.5	4.5
Fattening Calves	*14.3*	*0.0*	*0.0*	*0.4*	*85.2*	*15.0*	*0.0*	*0.0*	*0.4*	*84.6*	*21.6*	*0.0*	*0.3*	*0.5*	*77.6*
Pre-Weaned Calves	*41.2*	*32.1*	*26.3*	*0.4*	*0.0*	*39.3*	*34.1*	*26.2*	*0.4*	*0.0*	*41.2*	*21.1*	*37.3*	*0.5*	*0.0*
Breeding Cattle 1st Year	*37.0*	*48.5*	*14.1*	*0.4*	*0.0*	*38.0*	*47.4*	*14.2*	*0.4*	*0.0*	*33.7*	*38.8*	*27.0*	*0.5*	*0.0*
Breeding Cattle 2nd Year	*45.3*	*28.9*	*25.4*	*0.4*	*0.0*	*47.3*	*26.7*	*25.6*	*0.4*	*0.0*	*37.8*	*23.4*	*38.4*	*0.5*	*0.0*
Breeding Cattle 3rd Year	*50.5*	*29.0*	*20.0*	*0.4*	*0.0*	*51.4*	*27.9*	*20.3*	*0.4*	*0.0*	*42.2*	*22.5*	*34.8*	*0.5*	*0.0*
Fattening Cattle	*70.0*	*24.1*	*0.0*	*0.4*	*5.5*	*66.4*	*27.7*	*0.0*	*0.4*	*5.6*	*67.3*	*26.8*	*2.2*	*0.5*	*3.2*
Sheep (weighted average)	0.0	0.0	30.1	0.0	69.9	0.0	0.0	30.3	0.0	69.7	0.0	0.0	33.2	0.0	66.8
Swine (weighted average)	98.8	0.0	0.0	1.2	0.0	98.7	0.0	0.0	1.3	0.0	98.0	0.3	0.1	1.5	0.0
Buffalo (weighted average)	NA	NA	NA	NA	NA	47.5	26.8	25.6	0.0	0.0	38.1	23.5	38.4	0.0	0.0
Camels (weighted average)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.0	0.0	33.5	0.0	66.5
Deer (weighted average)	0.0	0.0	30.7	0.0	69.3	0.0	0.0	30.7	0.0	69.3	0.0	0.0	33.5	0.0	66.5
Goats (weighted average)	0.0	0.0	13.6	0.0	86.4	0.0	0.0	13.6	0.0	86.4	0.0	0.0	12.2	0.0	87.8
Horses (weighted average)	0.0	93.2	6.8	0.0	0.0	0.0	93.2	6.8	0.0	0.0	0.0	76.1	23.9	0.0	0.0
Mules and Asses (weighted average)	0.0	93.2	6.8	0.0	0.0	0.0	93.2	6.8	0.0	0.0	0.0	76.9	23.1	0.0	0.0
Poultry (weighted average)	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.5	0.0	99.5	0.0	0.0	2.6	0.0	97.4
Rabbits	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
Livestock NCAC (weighted average)	0.0	93.2	6.8	0.0	0.0	0.0	87.2	7.3	0.0	5.6	0.0	38.5	26.9	0.0	34.5

MS Distribution	2007					2010				
	%					%				
	Liquid / Slurry	Solid storage	Pasture range and paddock	Digesters	Other (Deep litter, Poultry manure)	Liquid / Slurry	Solid storage	Pasture range and paddock	Digesters	Other (Deep litter, Poultry manure)
Mature Dairy Cattle	67.4	13.6	17.7	1.3	0.0	66.9	14.3	16.9	1.8	0.0
Other Mature Cattle	49.5	20.2	29.0	1.3	0.0	47.9	17.9	32.4	1.8	0.0
Growing Cattle (weighted average)	45.6	23.9	25.3	1.3	4.0	45.2	25.6	23.4	1.8	4.1
Fattening Calves	*21.8*	*0.0*	*0.2*	*1.3*	*76.7*	*16.8*	*0.0*	*0.2*	*1.8*	*81.1*
Pre-Weaned Calves	*49.9*	*18.6*	*30.1*	*1.3*	*0.0*	*44.6*	*32.7*	*20.9*	*1.8*	*0.0*
Breeding Cattle 1st Year	*40.9*	*34.5*	*23.3*	*1.3*	*0.0*	*43.3*	*33.4*	*21.5*	*1.8*	*0.0*
Breeding Cattle 2nd Year	*41.4*	*20.8*	*36.5*	*1.3*	*0.0*	*43.2*	*20.7*	*34.3*	*1.8*	*0.0*
Breeding Cattle 3rd Year	*45.6*	*21.3*	*31.8*	*1.3*	*0.0*	*46.2*	*21.4*	*30.6*	*1.8*	*0.0*
Fattening Cattle	*62.3*	*29.2*	*4.3*	*1.3*	*2.9*	*57.6*	*33.2*	*4.0*	*1.8*	*3.4*
Sheep (weighted average)	0.0	0.0	39.2	0.0	60.8	0.0	0.0	33.7	0.0	66.3
Swine (weighted average)	94.5	0.1	1.2	4.1	0.0	94.0	0.3	0.1	5.6	0.0
Buffalo (weighted average)	42.3	21.1	36.5	0.0	0.0	44.5	21.2	34.3	0.0	0.0
Camels (weighted average)	0.0	0.0	40.2	0.0	59.8	0.0	0.0	34.5	0.0	65.5
Deer (weighted average)	0.0	0.0	40.2	0.0	59.8	0.0	0.0	34.5	0.0	65.5
Goats (weighted average)	0.0	0.0	7.1	0.0	92.9	0.0	0.0	10.0	0.0	90.0
Horses (weighted average)	0.0	78.7	21.3	0.0	0.0	0.0	74.4	25.6	0.0	0.0
Mules and Asses (weighted average)	0.0	75.2	24.8	0.0	0.0	0.0	79.3	20.7	0.0	0.0
Poultry (weighted average)	0.0	0.0	3.7	0.0	96.3	0.0	0.0	2.7	0.0	97.3
Rabbits	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
Livestock NCAC (weighted average)	0.0	34.7	28.7	0.0	36.6	0.0	31.8	28.0	0.0	40.2

5.3.2.4 Emission Factors N_2O

Estimation of direct N_2O emissions from Manure management relies basically on the same animal waste management systems as the estimation of CH_4 emissions (compare chapter 5.3.2.2). All emission factors are based on default values given in table 10.21 of the 2006 IPCC Guidelines (Table 5-12). For liquid/slurry systems a weighted emission factor was calculated based on the share of systems with and without natural crust cover. Data on occurrence of natural crusts on slurry tanks of Swiss farms was raised in the census conducted for the Swiss ammonia inventory AGRAMMON (Kupper et al. 2013). Results suggest that formation of thick and permanent natural crusts on slurry tanks is not widespread in Switzerland. The share of systems with crust formation ranges from 0.0 to 7.1% and leads to a N_2O emission factor that ranges from 0.0000 to 0.0004, respectively.

Table 5-12 Emission factors for calculating N_2O emissions from manure management.

Animal waste management system	**Emission factor**
	kg N_2O-N / kg N
Liquid/Slurry: with natural crust cover	0.005
Liquid/Slurry: without natural crust cover	0.000
Solid storage	0.005
Anaerobic digester	0.000
Cattle and swine deep bedding: no mixing	0.010
Poultry manure	0.001
Indirect emissions due to volatilisation	0.026

The emission factor for indirect N_2O emissions after volatilisation of NH_3 and NO_x from manure management systems was reassessed during a literature review by Bühlmann et al. 2015 and Bühlmann 2014. Due to the fragmented land use in Switzerland, where agricultural land use alternates with natural and semi-natural ecosystems over short distances, the share of volatilised nitrogen that is re-deposited in (semi-)natural habitats is on average higher than 55%. Thus, the assumption made in the 2006 IPCC Guidelines that a substantial fraction of the indirect emissions will in fact originate from managed land, cannot be applied to Switzerland. Accordingly, the overall emission factor for indirect emissions was estimated by calculating an area-weighted mean of the indirect emission factor for managed land (i.e. 0.01 based on IPCC 2006) and the indirect emission factor for (semi-)natural land (as provided in Bühlmann 2014). Due to slightly changing land use over the inventory time period, the resulting emission factor shows some small temporal variation around a mean value of 2.54%.

5.3.2.5 Activity Data N_2O

Activity data for N_2O emissions from Manure management were estimated according to equation 10.25 of the 2006 IPCC Guidelines:

$$N_2O_{D(mm)} = \left[\sum_S \left[\sum_T \left(N_{(T)} \bullet Nex_{(T)} \bullet MS_{(T,S)} \right) \right] \bullet EF_{3(S)} \right] \bullet \frac{44}{28}$$

$N_2O_{D(mm)}$ = direct N_2O emissions from manure management (kg N_2O/year)

$N_{(T)}$ = number of head of livestock species/category *T* (head)

$Nex_{(T)}$ = annual average N excretion per head of species/category *T* (kg N/head/year)

$MS_{(T,S)}$ = fraction of total annual nitrogen excretion for each livestock species/category *T* that is managed in manure management system *S*

$EF_{3(S)}$ = emission factor for direct N_2O emissions from manure management system *S* (kg N_2O-N/kg N)

44/28 = conversion of $(N_2O\text{-}N)_{(mm)}$ emissions to $N_2O_{(mm)}$ emissions

Livestock population

Activity data of all livestock categories covered by the official census were obtained from SBV (2014) and the SFSO (2014d). The respective data set was revised and harmonized during a joint effort of the Agroscope Reckenholz Tänikon Research Station (ART) and the Swiss College of Agriculture (SHL) in 2011 (ART/SHL 2012). Additionally to official statistical data, population data of livestock not covered by the agricultural census of the Swiss Federal Statistical Office were assessed (Poncet et al. 2007, Poncet et al. 2009, SFSO 2014e). For further details and additional data on a livestock sub-category level refer to chapter 5.2.2.3, Table 5-6 as well as Annex 3 A3.3.

Nitrogen excretion (N_{ex})

Data on nitrogen excretion per animal category (kg N/head/year) is country-specific and were obtained from Kupper et al. (2013) (Table 5-13). These values are based on the “Principles of Fertilisation in Arable and Forage Crop Production” (Flisch et al. 2009) and adjusted according to the livestock census data of the Swiss ammonia model AGRAMMON (Kupper et al. 2013). Unlike to the method in the IPCC Guidelines, the age structure of the animals and the different use of the animals (e.g. fattening and breeding) are considered. Standard nitrogen excretion rates are modified within the AGRAMMON model in order to account for changing agricultural structures and production techniques over the years (e.g. milk yield, use of feed concentrates, protein reduced animal feed etc.). This more disaggregated approach leads to considerable lower calculated nitrogen excretion rates compared to IPCC mainly because lower N_{ex}-rates of young animals are considered explicitly.

The nitrogen excretion rates are given on an annual basis, considering replacement of animals (growing cattle, swine, poultry, rabbits) and including excretions from corresponding offspring and other associated animals (sheep, deer, goats, swine, rabbits) (ART/SHL 2012).

Sheep in Switzerland are fed mainly on roughage from extensive pasture and meadows (Flisch et al. 2009) and are estimated to excrete approximately 8.0 kg N per head and year. This is considerably lower than IPCC default. However, nitrogen excretion is averaged over the whole population, of which roughly 40% are lambs and other immature animals. **Swine** show a significant decrease in nitrogen excretion rates until 2006, which can be explained by the increasing use of protein-reduced fodder (Kupper et al. 2013).

Table 5-13 Nitrogen excretion rates of Swiss livestock, 1990-2013. The complete time series by livestock subcategory level are provided in Annex 3 A3.3.

Nitrogen Excretion		1990-2011									
		1990	1995	2000	2005	2006	2007	2008	2009	2010	2011
		kg N/head/year									
Mature Dairy Cattle		102.7	105.5	109.7	113.2	113.3	113.9	114.2	114.7	114.9	115.0
Other Mature Cattle		80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0
Growing Cattle (weighted average)		33.1	33.4	33.6	33.1	33.2	33.2	33.2	33.4	33.4	33.4
	Fattening Calves	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*
	Pre-Weaned Calves	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*
	Breeding Cattle 1st Year	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*
	Breeding Cattle 2nd Year	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*
	Breeding Cattle 3rd Year	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*
	Fattening Cattle	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*
Sheep (weighted average)		7.5	7.6	8.1	8.1	8.2	8.3	8.2	8.5	8.5	8.5
Swine (weighted average)		13.4	12.8	10.5	9.4	9.2	9.1	9.2	9.2	9.2	9.2
Buffalo (weighted average)		NA	37.2	41.1	38.7	38.0	34.9	34.4	36.5	37.3	38.4
Camels (weighted average)		NA	NA	14.1	12.8	12.8	12.8	12.8	12.8	12.6	12.7
Deer (weighted average) 1)		20.0	21.9	22.3	21.9	22.1	22.1	22.4	22.5	22.4	22.4
Goats		10.5	10.4	10.6	10.5	10.6	10.5	10.5	10.7	10.6	10.8
Horses (weighted average)		43.6	43.5	43.6	43.7	43.7	43.7	43.7	43.7	43.7	43.7
Mules and Asses (weighted average)		15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7
Poultry (weighted average)		0.6	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Rabbits		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Livestock NCAC (weighted average)		38.8	33.8	14.5	12.5	12.4	12.5	12.2	12.3	12.6	12.6

Nitrogen Excretion		2012-2013	
		2012	2013
		kg N/head/year	
Mature Dairy Cattle		114.9	114.7
Other Mature Cattle		80.0	80.0
Growing Cattle (weighted average)		33.3	33.3
	Fattening Calves	*13.0*	*13.0*
	Pre-Weaned Calves	*34.0*	*34.0*
	Breeding Cattle 1st Year	*25.0*	*25.0*
	Breeding Cattle 2nd Year	*40.0*	*40.0*
	Breeding Cattle 3rd Year	*55.0*	*55.0*
	Fattening Cattle	*33.0*	*33.0*
Sheep (weighted average)		8.5	8.6
Swine (weighted average)		9.1	9.2
Buffalo (weighted average)		36.9	36.9
Camels (weighted average)		12.8	12.9
Deer (weighted average) 1)		22.5	23.0
Goats		10.8	10.9
Horses (weighted average)		43.7	43.8
Mules and Asses (weighted average)		15.7	15.7
Poultry (weighted average)		0.5	0.5
Rabbits		1.0	1.0
Livestock NCAC (weighted average)		12.5	12.6

1) Deer: Excretion per animal place

As an exception, nitrogen excretion of **mature dairy cattle** was separately calculated within the same feeding model that was used for CH_4 emissions from Enteric fermentation and from

Manure management (Agroscope 2014c, see also chapter 5.2.2.2). Nitrogen excretion of mature dairy cattle is dependent on milk production and feed properties. In the year 2003 yearly milk yield surpassed 6000 kg. To achieve yearly milk yields higher than 6000 kg the cows have to be fed with an increasing share of feed concentrates. Due to the energy dense feed concentrates, the ratio between net energy content and protein content increases. Since 2003 the increase in nitrogen excretion rate is thus slower than before, although milk yield increased more or less at the same rate from 1990 to 2011.

Manure management system distribution (MS)

The split of nitrogen flows into the different animal waste management systems and its temporal dynamic are based on the respective analysis in the AGRAMMON model (Kupper et al. 2013). The distribution is consistent with the allocation of volatile solids used for the calculation of CH_4 emissions from Manure management (for further information refer to chapter 5.3.2.2).

Volatilisation of NH_3 and NO_x from manure management systems

N_2O emissions from the deposition of volatilised nitrogen from manure management are based on NH_3 and NO_x emissions. Losses of ammonia from stables and manure storage systems to the atmosphere are calculated according to the Swiss ammonium emission model AGRAMMON (Kupper et al. 2013). Specific loss-rates for all major livestock categories are estimated based on agricultural structures and techniques (e.g. stable type, manure management system, measures to reduce NH_3 emissions). Accordingly, the overall fraction of nitrogen volatilised underlies certain temporal dynamics that can be explained by changes in agricultural management practices (e.g.the transition to more animal friendly housing systems). It ranges from 15.3 to 20.8%.

For the volatilisation of NO_x default values from the EMEP/EEA air pollutant emission inventory guidebook 2013 (EMEP/EEA 2013) were used, assuming that 50% and 25% of the nitrogen is present in the form of TAN (total ammonia nitrogen) in liquid/slurry and solid storage systems respectively. Accordingly, it is estimated that 0.005% and 0.25% of the total nitrogen in liquid/slurry and solid storage systems are lost to the atmosphere. In this context the management systems “anaerobic digestion” and “deep litter” are treated as liquid/slurry- and solid storage systems respectively.

Note that volatilisation from pasture, range and paddock manure is included under 3Db (Indirect N_2O emissions from managed soils). A graphical overview of the nitrogen flow system is given in Figure 5-6 and respective numbers are provided in Table 5-16.

5.3.3 Uncertainties and Time-Series Consistency

For the uncertainty analysis the input data from ART (2008a) were used and were updated with current activity and emission data as well as with new default uncertainties from the 2006 IPCC Guidelines. The arithmetic mean of the lower and upper bound was used for activity data and for emission factors in the Approach 1 analysis (Table 5-14).

For the Approach 2 analysis, asymmetric probability distributions as well as possible correlations of input data were considered.

For further results also consult chapter 1.7.1.

Table 5-14 Uncertainties for 3B Manure management 2013. (AD: Activity data; EF: Emission factor; CO: Combined).

Uncertainty 3B		**Approach 1**			**Approach 2**		
		AD	**EF**	**CO**	**low**	**high**	**mean**
		%			**%**		
CH_4		6.4	54.0	54.4	-54	54	54
N_2O direct	Liquid/slurry / Anaerobic digester	32.0	75.0	81.5	-76	89	83
N_2O direct	Solid storage / Deep bedding	32.0	75.0	81.5	-77	90	84
N_2O indirect	Indirect emissions	46.5	240.0	244.5	-77	125	101

The time series 1990–2013 are consistent, although the following issues should be considered:

- For time series consistency of livestock population data and gross energy intake see chapter 5.2.3.
- The MCF for liquid/slurry systems varies according to the development of the grazing management over the years as described under 5.3.2.2.
- Input data from the AGRAMMON-model are available for the years 1990 and 1995 (expert judgement and literature) as well as for 2002, 2007 and 2010 (extensive surveys on approximatively 3000 farms). Values in-between the assessment years were interpolated linearly whereas values beyond 2010 were kept constant and will be updated as new survey results become available.
- The emission factor for indirect N_2O emissions after volatilisation of NH_3 and NO_x from manure management systems varies according to varying land use as described in chapter 5.3.2.4.

5.3.4 Source-Specific QA/QC and Verification

General QA/QC measures are described in NIR chapter 1.2.3.

Since the CRF reporter was not available at the time of updating the EMIS data-base, the emissions from the EMIS data base were compared to data from last CRF submission tables (2014) for plausibility reasons.

All further category specific QA/QC activities are described in a separate document (ART 2013a). General information on agricultural structures and policies is provided and eventual differences between national and (IPCC) standard values are being analysed and discussed. Furthermore, comparisons with data from other countries were conducted and discussed where possible. ART 2013a is continuously updated with the most recent inventory data.

For quality of livestock population data and animal energy intake consult Chapter 5.2.4.

5.3.4.1 QA/QC and Verification CH_4

IPCC tables with data for estimating emission factors of all livestock categories (such as weight, feed digestibility, maximum CH_4 producing capacity (B_0) or daily excretion of volatile solids) were filled in, checked for consistency and confidence and compared with IPCC default values (refer to Annex 3 A3.3).

Factors for methane conversion (MCF) and manure management system distribution (MS) were analysed considering the national agricultural context. The estimated MCF-values for liquid/slurry systems in Switzerland are lower than the IPCC default value (liquid/slurry system, without natural crust cover, ≤ 10 °C). However, a relatively low MCF is supported by the fact that more than 80% of all liquid/slurry storage tanks are covered and approximately one third of the remaining tanks have a surface crust (Kupper et al. 2013). Furthermore, a series of laboratory measurements of MCF-values by the group of animal nutrition from the Swiss Federal Institute of Technology in Zürich yielded consistently low MCF-values (Zeitz et al. 2012).

During the past years studies were conducted to verify methane emissions at the regional scale comparing bottom-up estimates with atmospheric measurements (Hiller et al. 2014, Hiller et al. 2014a, Stieger 2014). For further information see section 5.2.4.

5.3.4.2 QA/QC and Verification N_2O

N_2O estimation is based on the Swiss ammonium emission model AGRAMMON that is documented in Kupper et al. (2013).

All relevant data needed for the calculation of N_2O emissions such as nitrogen excretion rates, manure management system distribution and N_2O emission factors were checked for consistency and were compared to the corresponding values of other countries and to the IPCC default value if available (ART 2013a).

As one of the most important parameters, nitrogen excretion rates were analysed in more detail. A comparison in 2011 revealed that bottom-up calculations of total nitrogen excretion in the Swiss GHG inventory are only 5-8% below the values of an independent top-down approach subtracting all nitrogen contained in animal products from the total amount of nitrogen in animal feedstuff produced in or imported into the country (Peter et al. 2006, Spiess 2005). Meanwhile, several recalculations were conducted and the total estimate of excreted nitrogen in the inventory has however increased somewhat closing the gap between the bottom-up and top-down approaches. Furthermore, N_{ex}-values for the most important animal categories (mature dairy cattle, other mature cattle and swine), being responsible for almost 70% of total nitrogen excretion, are similar to the values of the alternative gross energy approach suggested in the 2006 IPCC Guidelines. For mature dairy cows modelled values were compared to measurements of feeding trials of the animal nutrition group of the Swiss Federal Institute of Technology in Zürich. Measurements were on average almost 30 kg/head/year lower than modelled values. However, nitrogen intake as well as nitrogen losses through milk were in very good accordance. It is thus most likely, that some of the nitrogen excreted was lost (e.g. volatilised) before manure could be collected and nitrogen could be stabilised for measurements (e.g. Van Dorland et al. 2007).

5.3.5 Source-Specific Recalculations

Several new livestock categories are reported for the first time in the 2015 submission (buffalo, camels, deer, rabbits, livestock NCAC). On average the respective emissions sum up to 0.31% of total CH_4 emissions from Manure management (2.4 kt CO_2 equivalents) and 0.84% of total N_2O emissions from Manure management (2.9 kt CO_2 equivalents).

For the recalculation of energy requirements and milk yield see chapter 5.2.5. VS-excretion was recalculated according to the new estimates of gross energy intake and the respective parameters in the 2006 IPCC Guidelines.

MCF-values were recalculated according to the 2006 IPCC Guidelines and in order to better reflect Swiss specific manure management conditions (especially for liquid/slurry systems). In the course of this recalculation the assessment of emissions from anaerobic digesters was revised and harmonized with the respective estimates in the waste sector (see chapter 7.3).

The nitrogen excretion rate of mature dairy cattle was revised using the Agroscope feeding model (Agroscope 2014c). New nitrogen excretion rates are considerably higher than before (+ 6.6% on average).

New emission factors for NO_x volatilisation from Manure management were adopted based on EMEP/EEA (2013).

Emission factors for direct N_2O emissions from Manure management were adjusted to the 2006 IPCC Guidelines. Additionally the emission factor for indirect N_2O emissions from Manure management was revised. New country-specific estimates are based on the studies of Bühlmann et al. (2015) and Bühlmann (2014).

General information on recalculations is provided in chapter 10.

5.3.6 Source-Specific Planned Improvements

Planned improvements for future submissions are the further development, adaptation and verification of the dairy cow feeding model (GE, DE, VS-excretion, N-excretion).

In addition, further QA/QC checks of the new methodologies will be conducted and the respective documentation shall be updated.

5.4 Source Category 3C – Rice Cultivation

Rice cultivation is of minor importance in Switzerland. The agricultural land used for rice cultivation and the annual yield of rice are not estimated by the Swiss Farmers Union (SBV 2014). There is only some insignificant upland rice cultivation in the southern part of Switzerland. CH_4 Emissions are assumed to be zero. They are therefore not considered in the emission calculation.

5.5 Source Category 3D – Agricultural Soils

5.5.1 Source Category Description

Approach 1 and Approach 2 Key Category 3D:

3Da: Direct N_2O emissions from managed soils (level and trend)
3Db: Indirect N_2O emissions from managed soils (level and trend)

The source category 3D includes direct and indirect N_2O emissions from managed soils (Table 5-15). Direct emissions are further subdivided in emissions from 1. Inorganic N fertilisers, 2. Organic N fertilisers, 3. Urine and dung deposited by grazing animals, 4. Crop residues, 5. Mineralisation/immobilisation associated with loss/gain of soil organic matter, 6. Cultivation of organic soils (i.e. histosols) and 7. Other (i.e. Domestic synthetic fertilisers). Indirect N_2O emissions are further subdivided in 1. Atmospheric deposition and 2. Nitrogen leaching and run-off.

Table 5-15 Specification of source category 3D Agricultural soils. (AD: Activity data; EF: Emission factor).

3D	Source	Specification	Data Source
3Da	Direct N_2O emissions from managed soils	1. Inorganic N fertilisers 2. Organic N fertilisers (animal manure applied to soils, sewage sludge applied to soils, other organic fertilisers applied to soils) 3. Urine and dung deposited by grazing animals 4. Crop residues (inc. residues from meadows and pasture) 5. Mineralisation/immobilisation associated with loss/gain of soil organic matter 6. Cultivation of organic soils (i.e. histosols) 7. Other (domestic synthetic fertilisers)	AD: SBV 2014, SFSO 2014d, SFSOe, ART/SHL 2012, Agricura 2014, Flisch et al. 2009, FAL/RAC 2001, Kupper et al. 2013, Schmid et al. 2000, Walther et al. 1994 EF: IPCC 2006
3Db	Indirect N_2O emissions from managed soils	1. Atmospheric deposition 2. Nitrogen leaching and run-off	AD: Kupper et al. 2013, Schmid et al. 2000, Stehfest and Bouwman 2006, Hürdler et al. 2015 EF: IPCC 2006, Bühlmann et al. 2015, Bühlmann 2014,

Furthermore, NO_x emissions from manure management and managed soils as well as NMVOC emissions are estimated.

Direct and indirect N_2O emissions from managed soils have decreased since 1990 in almost all major sub-categories. Only N_2O emissions from 3Da3 (Urine and dung deposited by grazing animals) increased due to a higher share of manure excreted on pasture, range and paddock. NO_x emissions have declined by more than 20% since 1990. The general trends can be explained by a reduction in the number of cattle and a reduced input of mineral fertilisers due to the introduction of the “Proof of Ecological Performance (PEP)” requiring a balanced fertiliser management (ART 2013a, Leifeld and Fuhrer 2005).

The most significant N_2O emission sources are animal manure applied to soils (Ø 27%), nitrogen input from atmospheric deposition (Ø 22%), inorganic nitrogen fertilisers (Ø 15%) and urine and dung deposited by grazing animals (Ø 11%).

5.5.2 Methodological Issues

5.5.2.1 Methodology

For the calculation of N_2O emissions from Agricultural soils a country-specific Tier 2 method was applied that is based on the IULIA model from Schmid et al. (2000). IULIA is an IPCC-derived method for the calculation of N_2O emissions from agriculture that basically uses the same emission factors, but adjusts the activity data to the particular situation of Switzerland. IULIA is continuously updated. New values for nitrogen excretion rates, manure management system distribution and ammonium emission factors from the Swiss ammonium model AGRAMMON were adopted (Kupper et al. 2013). Furthermore, the updated version of the "Principles of Fertilisation in Arable and Forage Crop Production" (GruDAF; Flisch et al. 2009) was used instead of obsolete data from FAL/RAC 2001 and Walther et al. 1994. Most recently, additional livestock categories, new emission factors for indirect N_2O emissions from atmospheric deposition, new estimates for nitrogen leaching and run-off as well as new NO_x emission factors were introduced.

The modelling of the N_2O emissions is conducted in Agroscope (2015) and is consistent with source category 3B N_2O emissions from Manure management. The model structure is displayed in Figure 5-6 and the corresponding amounts of nitrogen are given in Table 5-16.

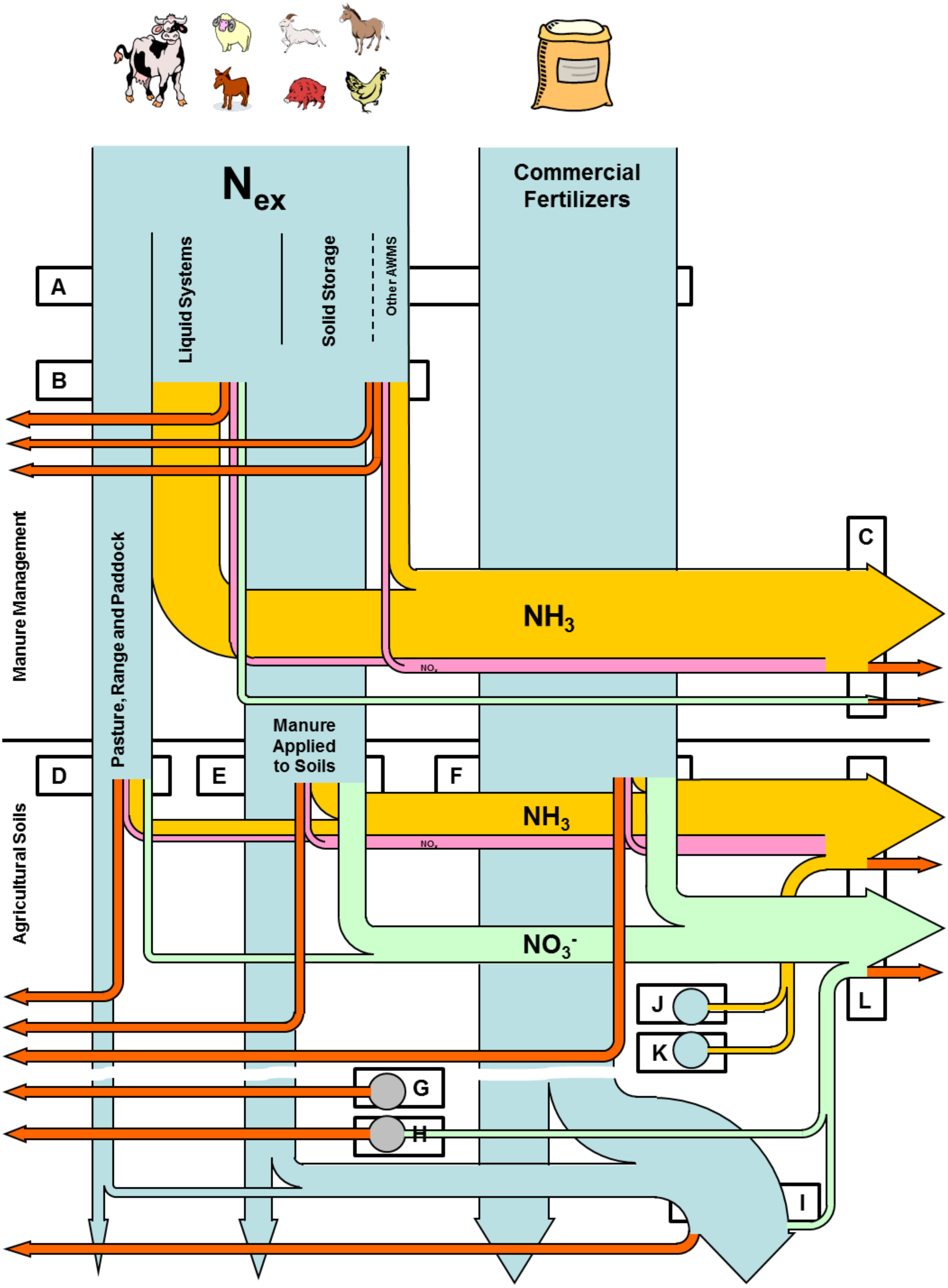


Figure 5-6 Diagram depicting the methodology of the approach to calculate the N_2O emissions in agriculture (red arrows). Black frames and the respective letters refer to the nitrogen flows in Table 5-16. Note that the figure shows explicitly the methodology of the approach and not necessarily the physical nitrogen flows.

Table 5-16 Nitrogen flows of the N-flow-model for Swiss agriculture. Letters refer to the letters in Figure 5-6. Processes refer to the nitrogen flows in the black frames in Figure 5-6 from left to right or from top to bottom.

	Process	**Amount of N**			**CRF table**
		1990	**2013**		
		tN			
A	1 Pasture, range and paddock	13'578	23'531	= B	3.Da3
	2 Liquid/slurry systems	91'914	74'107		3.B(b)
	3 Solid storage	35'909	20'851		3.B(b)
	4 Other AWMS	8'447	14'321		3.B(b)
	5 Commercial fertiliser	75'339	49'487	= F	3.Da1,2,7
B	1 Pasture, range and paddock	13'578	23'531	= A1-A4	3.Da3
	2 NH_3 volatilisation housing	11'347	15'094		3.B(b)5
	3 N_2O emission liquid/slurry	0	23		3.B(b)
	4 NO_x volatilisation liquid/slurry and digester	5	4		3.B(b)5
	5 Leaching manure management	0	0		3.B(b)5
	6 Manure applied to soils	115'195	86'424		3.Da2
	7 N_2O emission solid storage	180	104		3.B(b)
	8 N_2O emission other AWMS	46	56		3.B(b)
	9 NO_x volatilisation solid storage and deep litter	109	78		3.B(b)5
	10 NH_3 volatilisation storage	9'388	7'497		3.B(b)5
C	1 NH_3 deposition manure management	20'734	22'591	= B2+B10	3.B(b)5
	2 NO_x deposition manure management	114	82	= B4+B9	
	3 Leaching manure management	0	0	= B5	
D	1 Available N PR&P	9'389	16'623	= B1	
	2 N_2O emission PR&P	260	447		3.Da3
	3 NO_x volatilisation PR&P	75	129		
	4 NH_3 volatilisation PR&P	674	1'205		
	5 Leaching and run-off PR&P	3'181	5'126		
E	1 Available N animal manure	55'391	45'679	= B6	
	2 N_2O emission application animal manure	1'152	864		3.Da2
	3 NO_x volatilisation application animal manure	634	475		
	4 NH_3 volatilisation application animal manure	31'034	20'577		
	5 Leaching and run-off application animal manure	26'985	18'828		
F	1 Available N com. fertiliser	51'927	35'880	= A5	
	2 N_2O emission application com. fertiliser	753	495		3.Da1,2,7
	3 NO_x volatilisation application com. fertiliser	414	272		
	4 NH_3 volatilisation application com. fertiliser	4'595	2'059		
	5 Leaching and run-off application com. fertiliser	17'649	10'781		
G	1 Cultivation of organic soils (ha)	*18'493*	*17'802*		3.Da6
H	1 Mineralisation/immobilisation soil organic matter	6	7		3.Da5
I	1 N in crop residues pasture, range and paddock	21'689	21'794		3.Da4
	2 N in crop residues arable crops	11'337	10'074		
J	1 NH_3 volatilisation agricultural area	2'134	2'100		
K	1 NH_3 volatilisation alpine area	269	240		
L	1 NH_3 deposition fertiliser appl. and PR&P	36'303	23'840	= D4+E4+F4	3.Db1
	2 NO_x deposition fertiliser appl. and PR&P	1'123	877	= D3+E3+F3	
	3 NH_3 deposition agricultural and alpine area	2'403	2'340	= J+K	
	4 Leaching and run-off fertiliser appl. and PR&P	47'815	34'736	= D5+E5+F5	3.Db2
	5 Leaching and run-off mineralisation SOM	1	1		
	6 Leaching and run-off crop residues	7'737	6'943		

5.5.2.2 Direct N_2O emissions from managed soils (3Da)

Calculation of Direct N_2O emissions from managed soils is based on IPCC 2006 equation 11.2 including six terms for activity data and three different emission factors:

$$N_2O_{Direct} - N = (F_{SN} + F_{ON} + F_{CR} + F_{SOM}) \bullet EF_1 + F_{OS} \bullet EF_2 + F_{PRP} \bullet EF_3$$

N_2O_{Direct}-N = annual direct N_2O–N emissions produced from managed soils (kg N_2O–N/year)

F_{SN} = annual amount of synthetic fertiliser N applied to soils (kg N/year)

F_{ON} = annual amount of animal manure, compost, sewage sludge and other organic N additions applied to soils (kg N/year)

F_{CR} = annual amount of N in crop residues, including N-fixing crops, returned to soils (kg N/year)

F_{SOM} = annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes of land use or management (kg N/year)

F_{OS} = annual area of managed/drained organic soils (ha)

F_{PRP} = annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock (kg N/year)

EF_1 = emission factor for N_2O emissions from N inputs (kg N_2O–N/kg N input)

EF_2 = emission factor for N_2O emissions from drained/managed organic soils (kg N_2O–N/ha/year)

EF_3 = emission factor for N_2O emissions from urine and dung N deposited on pasture, range and paddock by grazing animals (kg N_2O–N/kg N input)

Emission Factors

Emission factors for calculating Direct N_2O emissions from managed soils were all based on default values as provided in the 2006 IPCC Guidelines (Table 5-17). Due to the lack of data no fertiliser specific emission factors were applied for EF_1. The emission factor for urine and dung deposited by grazing animals was calculated as the weighted mean between the emission factor for cattle, poultry and pigs ($EF_{3PRP,CPP}$ = 0.02) and the emission factor for sheep and “other animals” ($EF_{3PRP,SO}$ = 0.01) according to the shares of nitrogen excreted by the respective animals.

Table 5-17 Emission factors for calculating direct N_2O emissions from managed soils (IPCC 2006). Blue: annually changing parameters, value for 2013.

Emission Source	Emission factor
EF_1 Inorganic N fertilisers (kg N_2O-N/kg)	0.0100
EF_1 Organic N fertilisers (kg N_2O-N/kg)	0.0100
EF_1 Crop residue (kg N_2O-N/kg)	0.0100
EF_1 Mineralisation/immobilisation soil organic matter (kg N_2O-N/kg)	0.0100
EF_1 Other (domestic synthetic fertilisers) (kg N_2O-N/kg)	0.0100
EF_2 Cultivation of organic soils (kg N_2O-N/ha)	8.0000
EF_3 Urine and dung deposited by grazing animals (kg N_2O-N/kg)	0.0190

Activity Data

Activity data for calculation of Direct soil emissions includes 1. Inorganic N fertilisers, 2. Organic N fertilisers, 3. Urine and dung deposited by grazing animals, 4. Crop residues, 5. Nitrogen from mineralisation/immobilisation associated with loss/gain of soil organic matter 6. Area of organic soils (i.e. histosols) and 7. Other (i.e. Domestic inorganic fertilisers).

Emissions from **inorganic nitrogen fertilisers** include urea and other mineral fertilisers (mainly ammonium-nitrate). The amount of nitrogen input due to these fertilisers is obtained from Agricura (2014). Fertiliser statistics were based on sales statistics of the compulsory storekeepers of fertilisers (Pflichtlagerhalter) and small importers. Agricura conducts plausibility checks with import-data received by the Directorate General of Customs (Oberzolldirektion). It is estimated that 4% of the mineral fertilisers are used for non-agricultural purposes (Kupper et al. 2013). These fertilisers are used in public green areas, sports grounds and home gardens and are reported under 3Da7 **Other (Domestic inorganic fertilisers)**. In some occasions, as for instance for the estimation of Indirect N_2O emissions from managed soils, the sum of urea, other mineral fertilisers, sewage sludge, other organic fertilisers and domestic fertilisers is referred to as “commercial fertilisers” (see also Figure 5-6 and Table 5-16).

Organic nitrogen fertilisers include animal manure, sewage sludge and other organic fertilisers. The amount of nitrogen in **animal manure applied to soils** is calculated according to the methods described in chapter 5.3.2.5. As suggested in chapter 10.5.4. and equation 10.34 of the 2006 IPCC Guidelines, all nitrogen excreted on pasture, range and paddock as well as all nitrogen volatilised prior to final application to managed soils is subtracted from the total excreted manure (for the estimation of N-volatilisation see chapter 5.3.2.5, compare also Figure 5-6 and Table 5-19). $Frac_{GASM}$ in CRF-table 3.D represents the amount of nitrogen volatilised as NH_3, NO_x and N_2O from housing and manure storage divided by the manure excreted in the stable (liquid/slurry, solid storage, digesters, deep litter and poultry manure). The nitrogen input from manure applied to soils under 3Da2a in CRF-table 3.D can thus be calculated with the numbers given in CRF-table 3.B(b) and 3.D. Nitrogen from bedding material was not accounted for under animal manure applied to soils. The respective nitrogen is included in the nitrogen returned to soils as crop residues.

The amount of **sewage sludge** applied to agricultural soils was estimated according to Kupper et al. (2013). Since 2003 the use of sewage sludge as fertiliser is prohibited in

Switzerland. However, a transition period applies for some areas. Cantons could therefore prolong this period until 2008 in individual cases (UVEK 2003). **Other organic fertilisers** include compost as well as liquid and solid digestates from biogas plants and are also estimated according to Kupper et al. (2013).

Calculation of emissions from **urine and dung deposited by grazing animals** is based on equation 11.5 of the 2006 IPCC Guidelines. Estimation of total livestock nitrogen excretion was described under 5.3.2.5. The share of manure nitrogen excreted on pasture, range and paddock was estimated according to the AGRAMMON-model (Kupper et al. 2013). For each livestock category the share of animals that have access to grazing, the number of days per year they are actually grazing as well as the number of hours per day grazing takes place was assessed. Estimates are based on values from the literature and expert judgement (1990, 1995) and on surveys on approximatively 3000 farms (2000, 2007, 2010).

N_2O emissions from **crop residues** are based on the amount of nitrogen in crop residues returned to soil. For **arable crops**, data on total annual crop yields were adopted from the statistical yearbooks of the Swiss Farmers Union (SBV 2014). Subsequently the relationship between nitrogen returned in crop residues and fresh matter crop yield was determined for each crop and hereafter the overall amount of nitrogen returned to soils was calculated as follows:

$$F_{CR,AC} = \sum_{T} \left(Y_T \bullet \frac{NR_T}{SY_T} \right)$$

$F_{CR,AC}$ = amount of nitrogen in crop residues from arable crops returned to soils (t N)

Y_T = amount of fresh matter crop yield for crop *T* (t)

NR_T = standard amount of nitrogen in crop residues for crop *T* (dt/ha)

SY_T = standard amount of fresh matter crop yield for crop *T* (dt/ha)

Standard values for fresh matter crop yields and nitrogen contained in crop residues are given in the “Principles of Fertilisation in Arable and Forage Crop Production” (FAL/RAC 2001 and Flisch et al. 2009). For sugar beet and fodder beet it is assumed that 10% of the crop residues are removed from the fields for animal fodder.

Crop residues from **meadows and pastures** were also assessed. Two third of the agricultural land consists of grassland which underscores the importance of this source for Switzerland:

$$F_{CR,MP} = \sum_{P} \left(A_P \bullet \frac{SY_{DM,P}}{10} \bullet N_{DM,P} \div 1000 \bullet R_P \right)$$

$F_{CR,MP}$ = amount of nitrogen in crop residues from meadows and pastures returned to soils (t N)

A_P = area of meadow and pasture of type *P* (ha)

$SY_{DM,P}$ = standard dry matter yield per area of meadow and pasture of type *P* (dt/ha)

$N_{DM,P}$ = dry matter nitrogen content of meadow and pasture of type *P* (kg/t)

R_P = ratio of residues to harvested yield for meadows and pasture of type *P* (kg/kg)

Areas of intensive meadows, natural meadows, pasture and alpine and Jurassic pasture were obtained from SBV (2014) and from the SFSO (2014d). Standard dry matter yields per area, nitrogen content of dry matter as well as % yield losses were based on the IULIA model (Schmid et al. 2000).

Estimated values of total crop production, nitrogen incorporated with crop residues $F_{(CR)}$, residue/crop ratio, dry matter fraction of residues and nitrogen content of residues are provided in Annex 3 A3.3.

Assessment of nitrogen **mineralisation/immobilisation associated with loss/gain of soil organic matter** was conducted based on data from the LULUCF sector. For reasons of consistency, losses and gains of soil organic matter on cropland and grasslands were accounted for. The same methodology as described under 6.10.2 was applied. Nitrogen mineralisation was estimated by dividing the carbon loss on cropland remaining cropland and grassland remaining grassland with a C/N-ratio of 9.8 according to Leifeld et al. (2007). It should be noted that the carbon losses were assessed on a land use subcategory level without taking account of carbon gains. Consequently the carbon losses used here are not identical with the net carbon stock changes reported in the CRF tables. N_2O emissions from nitrogen mineralisation of land converted to cropland or land converted to grassland are reported under source category 4(III) "Direct nitrous oxide (N_2O) emissions from nitrogen (N) mineralisation/immobilisation associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils".

Estimates of N_2O emissions from **cultivated organic soils** are based on the area of cultivated organic soils and the IPCC default emission factor for N_2O emissions from cultivated organic soils (IPCC 2006). The area of cultivated organic soils corresponds to the total area of organic soils under cropland and grassland as reported in CRF-table 4.B and 4.C (see also 6.2.2).

The relevant activity data for calculating N_2O emissions from soils is displayed in Table 5-18. Additional information is given in Annex 3 A3.3.

Table 5-18 Activity data for calculating Direct N_2O emissions from managed soils (1990-2013).

Activity Data		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
		t N/yr									
1. Inorganic N fertilisers	Urea	17'000	12'500	12'171	11'842	11'514	11'185	10'856	7'900	6'698	6'996
	Other mineral fertilisers	49'912	54'604	54'741	50'366	47'046	47'375	45'592	40'964	42'358	44'364
2. Organic N fertilisers	a. Animal manure	115'195	113'859	111'200	109'516	108'361	106'426	103'795	99'670	97'604	93'591
	b. Sewage sludge	4'815	4'840	4'866	4'891	4'916	4'942	4'624	4'307	3'990	3'673
	c. Other organic fertilisers	824	935	1'046	1'157	1'268	1'380	1'416	1'453	1'490	1'526
3. Urine and dung deposited by grazing animals		13'578	13'860	13'937	13'899	14'147	14'333	16'222	17'532	18'871	19'729
4. Crop residues	Arable crops	11'337	11'172	11'056	11'251	10'637	10'841	12'149	11'746	11'808	10'560
	Residues PR&P	21'689	21'717	21'809	21'700	21'372	21'744	21'837	21'911	21'949	21'898
5. Min./imm. associated with loss/gain of SOM		6	6	6	6	6	6	6	6	7	7
6. Cultivation of organic soils (ha)		18'493	18'458	18'423	18'391	18'353	18'314	18'276	18'241	18'205	18'170
7. Other (domestic inorganic fertilisers)		2'788	2'796	2'788	2'592	2'440	2'440	2'352	2'036	2'044	2'140

Activity Data		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
		t N/yr									
1. Inorganic N fertilisers	Urea	7'978	8'169	8'385	7'066	8'232	6'910	6'254	8'680	6'905	5'551
	Other mineral fertilisers	42'902	46'647	45'087	44'006	43'224	43'394	43'090	43'064	41'863	40'433
2. Organic N fertilisers	a. Animal manure	90'885	89'568	87'107	86'105	85'333	86'285	86'510	86'650	88'540	87'613
	b. Sewage sludge	3'356	2'934	2'513	2'091	1'670	1'248	1'054	859	573	286
	c. Other organic fertilisers	1'563	1'725	1'887	2'049	2'211	2'373	2'562	2'751	3'096	3'442
3. Urine and dung deposited by grazing animals		21'913	23'689	25'276	24'967	24'522	24'552	24'626	24'594	24'802	24'346
4. Crop residues	Arable crops	11'894	10'401	11'466	9'759	11'832	11'533	10'555	11'532	11'511	11'895
	Residues PR&P	21'900	21'932	21'922	22'020	22'029	21'845	21'849	21'928	21'905	21'922
5. Min./imm. associated with loss/gain of SOM		7	7	7	7	7	6	6	5	4	6
6. Cultivation of organic soils (ha)		18'134	18'098	18'063	18'027	17'991	17'970	17'937	17'904	17'883	17'853
7. Other (domestic inorganic fertilisers)		2'120	2'284	2'228	2'128	2'144	2'096	2'056	2'156	2'032	1'916

Activity Data		2010	2011	2012	2013
		t N/yr			
1. Inorganic N fertilisers	Urea	7'424	6'788	5'589	6'015
	Other mineral fertilisers	45'856	40'156	39'723	37'857
2. Organic N fertilisers	a. Animal manure	87'509	87'220	87'183	86'424
	b. Sewage sludge	0	0	0	0
	c. Other organic fertilisers	3'787	3'787	3'787	3'787
3. Urine and dung deposited by grazing animals		23'920	23'690	23'658	23'531
4. Crop residues	Arable crops	10'461	12'195	11'258	10'074
	Residues PR&P	21'925	21'972	21'926	21'794
5. Min./imm. associated with loss/gain of SOM		7	7	7	7
6. Cultivation of organic soils (ha)		17'822	17'790	17'759	17'802
7. Other (domestic inorganic fertilisers)		2'220	1'956	1'888	1'828

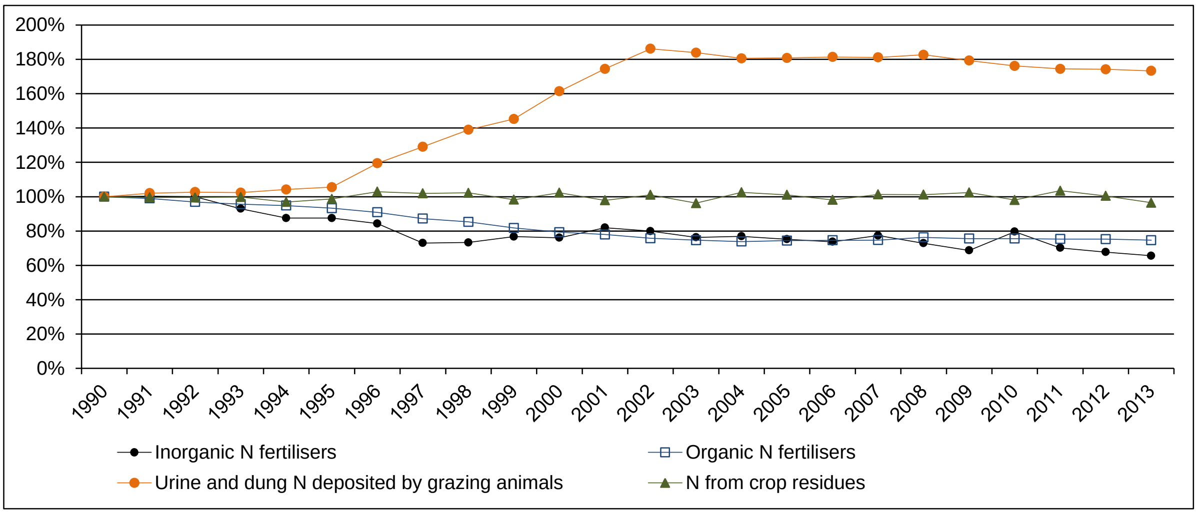


Figure 5-7 Relative development of the most important activity data for Direct N_2O emissions from managed soils 1990-2013.

Figure 5-7 depicts the development of the most important activity data for Direct N_2O emissions from managed soils. The use of inorganic N-fertiliser declined mainly during the 1990s due to the agricultural policy reforms and the introduction of the “Proof of Ecological Performance (PEP)” that requires a balanced fertiliser management. Simultaneously, nitrogen input from animal manure declined due to declining livestock populations (mainly cattle). Urine and dung deposited by grazing animals increased substantially due to the shift to more animal-friendly livestock husbandry in the course of the agricultural policy reforms during the 1990s and the early 20^{th} century (see also chapter 5.3.2.2). N inputs from crop residues remained more or less constant during the inventory time period due to more or less stable crop production.

5.5.2.3 Indirect N_2O emissions from atmospheric deposition of N volatilised from managed soils (3Db1)

N_2O emissions from atmospheric deposition of N volatilised from managed soil were estimated based on equations 11.9 and 11.11 of the 2006 IPCC Guidelines. However, the method was adapted to the far more detailed approach of Switzerland:

$$N_2O_{(ATD)}-N = \begin{bmatrix} \sum_i \left(F_{CN_i} \bullet Frac_{GASF_i}\right) \\ +\sum_T \left(F_{AM_T} \bullet Frac_{GASM_T}\right) \\ +\sum_T \left(F_{PRP_T} \bullet Frac_{GASP_T}\right) \\ +NH3_{AS} + NH3_{AA} \end{bmatrix} + \begin{bmatrix} \left(F_{CN} + F_{AM}\right) \bullet Frac_{NOXA} \\ +F_{PRP} \bullet Frac_{NOXP} \end{bmatrix} \bullet EF_4$$

$N_2O_{(ATD)}$-N = annual amount of N_2O–N produced from atmospheric deposition of N volatilised from managed soils (kg N_2O–N/year)

F_{CNi} = annual amount of commercial fertiliser N of type *i* applied to soils (kg N/year)

$Frac_{GASFi}$ = fraction of commercial fertiliser N of type *i* that volatilises as NH_3 (kg N/kg N)

F_{AMT} = annual amount of managed animal manure N of livestock category *T* applied to soils (kg N/year)

$Frac_{GASMT}$ = fraction of applied animal manure N of livestock category *T* that volatilises as NH_3 (kg N/kg N)

F_{PRPT} = annual amount of urine and dung N deposited on pasture, range and paddock by grazing animals of livestock category *T* (kg N/year)

$Frac_{GASPT}$ = fraction of urine and dung N deposited on pasture, range and paddock by grazing animals of livestock category *T* that volatilises as NH_3 (kg N/kg of N)

$NH3_{AS}$ = ammonia volatilised from the vegetation cover on agricultural soils (kg N/ha)

$NH3_{AA}$ = ammonia volatilised from the vegetation cover from the alpine area (kg N/ha)

F_{CN} = total amount of commercial fertiliser N applied to soils (kg N/year)

F_{AM} = total amount of managed animal manure N applied to soils (kg N/year)

$Frac_{NOXA}$ = fraction of applied N (commercial fertilisers and animal manure) that volatilises as NO_x (kg N/kg N)

F_{PRP} = total amount of urine and dung N deposited on pasture, range and paddock by grazing animals (kg N/year)

$Frac_{NOXP}$ = fraction of urine and dung N deposited on pasture, range and paddock that volatilises as NO_x (kg N/kg of N)

EF_4 = emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces (kg N_2O-N/ kg N volatilised)

Emission Factor

The emission factor for indirect N_2O emissions from atmospheric deposition of N volatilised from managed soils is the same as that used for the assessment of indirect N_2O emissions after volatilisation of NH_3 and NO_x from manure management systems. The emission factor was reassessed by a literature review by Bühlmann et al. 2015 and Bühlmann 2014. Due to slightly changing land use, the resulting emission factor shows some small variations around a mean value of 2.54%. For further information see chapter 5.3.2.4.

Activity Data

The estimation of volatilisation of ammonia and NO_x was harmonized with the Swiss ammonia model AGRAMMON using the same emission factors and basic parameters (Table 5-19). Losses of commercial fertiliser nitrogen, animal manure N applied to soils, urine and dung N deposited on pasture, range and paddock by grazing animals as well as ammonia losses from agricultural soils and alpine areas due to processes in the vegetation cover were considered. For the calculation of NH_3 emissions, changes of agricultural structures (changes to more animal friendly housing systems) and techniques (manure management, measures to reduce NH_3 emissions) are considered and explain temporal dynamics.

Ammonia volatilisation from **commercial fertiliser N** was estimated separately for synthetic fertilisers (urea and other synthetic fertilisers), sewage sludge, and other organic fertilisers (compost, liquid and solid digestates from biogas plants). Ammonia volatilisation of nitrogen in synthetic fertilisers is 15% for urea and 2% for other synthetic fertilisers. These estimates are based on a literature review by van der Weerden and Jarvis (1997) who examined ammonia emission factors for ammonium nitrate and urea for grassland and cropland soils. The emission factors for all other synthetic fertilisers (as straight and compound fertilisers) were assumed to be similar to that for ammonium nitrate. Ammonia emission factors for sewage sludge range from 20% to 26% depending on the composition of the sludge (Kupper et al. 2013). Other organic fertilisers include compost as well as liquid and solid digestates. Ammonia emission factors are 3.4% for compost, 21% - 30% for liquid digestate and 4.0% for solid digestate. The ammonia loss rate for liquid digestates decreased from 2008 until 2013 due to the increasing use of trailing hoses during field application.

Total $Frac_{GASF}$ as reported in CRF-table 3.D declined considerably from 6.1% in 1990 to 4.2% in 2013 due to a change in the shares of the different commercial fertilisers: the use of urea and sewage sludge (which both have high NH_3 emission factors) has declined since 1990.

Different ammonia loss factors were used for **animal manure N applied to soils** from different livestock categories according to the detailed approach of the AGRAMMON model (Kupper et al. 2013). Overall weighted $Frac_{GASMT}$ for animal manure applied to soils slightly declined from 27% in the early 1990s to 24% in 2013.

Ammonia volatilisation from **urine and dung N deposited on pasture, range and paddock by grazing animals** was also assessed individually for each livestock category. Weighted mean loss rates ($Frac_{GASPT}$) range from 5.0% to 5.2%.

As an additional source, **volatilisation of ammonia from the vegetation cover** on agricultural soils and from alpine areas was accounted for (Kupper et al. 2013), assuming that 2.0 kg NH_3 -N/ha and 0.5 kg NH_3-N/ha are emitted from agricultural land and the alpine area, respectively (Schjoerring and Mattsson 2001).

NO_x emissions were estimated separately for applied fertiliser N (commercial fertilisers, animal manure) and for urine and dung N deposited on pasture, range and paddock by grazing animals. NO_x emission factors for applied fertilisers and for urine and dung N deposited on pasture, range and paddock are 0.55% each, based on Stehfest and Bouwman (2006).

Nitrogen pools and flows for calculating Indirect N_2O emissions from managed soils are displayed in Table 5-20. Additional information is given in Annex 3 A3.3.

Table 5-19 Overview of NH_3 and NOx emission factors used for the assessment of Indirect N_2O emissions from atmospheric deposition (1990–2013). Complete time series by livestock subcategory level are provided in Annex 3 A3.3.

Emission Factors Volatilisation	**1990-2011**									
	1990	**1995**	**2000**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
	%									
NH_3 from commercial fertiliser N ($Frac_{GASFi}$)	6.10	5.83	5.34	4.34	4.19	4.61	4.31	4.04	4.11	4.22
Urea	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Other Mineral Fertilisers	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Recycling Fertilisers (weighted average)	17.58	19.74	20.27	13.47	12.90	12.32	11.83	10.91	9.58	9.58
Sewage Sludge	20.00	23.94	26.07	26.07	26.07	26.07	26.07	26.07	26.07	26.07
Compost	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43
Digestate Liquid	30.00	30.00	30.00	30.00	30.00	30.00	27.00	24.00	21.00	21.00
Digestate Solid	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
NH_3 from application of animal manure N ($Frac_{GASMT}$)	26.94	27.07	25.29	25.06	25.31	25.53	25.01	24.41	23.82	23.82
Mature Dairy Cattle	29.41	29.53	28.05	27.76	27.89	28.02	27.39	26.76	26.13	26.13
Other Mature Cattle	27.35	27.05	25.61	26.71	27.25	27.76	27.26	26.74	26.21	26.21
Growing Cattle (weighted average)	27.67	27.81	26.07	26.45	26.88	27.30	26.75	26.27	25.76	25.74
Sheep (weighted average)	8.81	9.36	9.34	10.48	10.89	11.32	11.19	11.07	10.96	10.96
Swine (weighted average)	22.85	22.43	20.62	20.55	20.79	21.06	20.41	19.77	19.12	19.13
Other Livestock (weighted average)	11.46	12.24	11.50	11.50	11.55	11.59	11.78	12.05	12.33	12.40
NH_3 from urine and dung N deposited on PR&P ($Frac_{GASPT}$)	4.96	5.00	5.07	5.16	5.17	5.20	5.16	5.13	5.10	5.11
Mature Dairy Cattle	4.95	4.93	4.87	4.82	4.81	4.80	4.80	4.80	4.80	4.80
Other Mature Cattle	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98
Growing Cattle (weighted average)	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98
Sheep (weighted average)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Swine (weighted average)	NA	NA	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00
Other Livestock (weighted average)	5.00	6.97	8.04	9.56	9.75	10.14	9.51	8.99	8.56	8.69
NH_3 from Agricultural Soils (kg/ha/year)	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
NH_3 from Alpine Area (kg/ha/year)	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
NO_x from applied fertilisers ($Frac_{NOXA}$)	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
NO_x from urine and dung N deposited on PR&P ($Frac_{NOXP}$)	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55

Emission Factors Volatilisation	**2012-2013**	
	2012	**2013**
	%	
NH_3 from commercial fertiliser N ($Frac_{GASFi}$)	3.99	4.16
Urea	15.00	15.00
Other Mineral Fertilisers	2.00	2.00
Recycling Fertilisers (weighted average)	9.58	9.58
Sewage Sludge	26.07	26.07
Compost	3.43	3.43
Digestate Liquid	21.00	21.00
Digestate Solid	4.00	4.00
NH_3 from application of animal manure N ($Frac_{GASMT}$)	23.80	23.81
Mature Dairy Cattle	26.13	26.13
Other Mature Cattle	26.21	26.21
Growing Cattle (weighted average)	25.72	25.72
Sheep (weighted average)	10.96	10.96
Swine (weighted average)	19.15	19.14
Other Livestock (weighted average)	12.42	12.45
NH_3 from urine and dung N deposited on PR&P ($Frac_{GASPT}$)	5.11	5.12
Mature Dairy Cattle	4.80	4.80
Other Mature Cattle	4.98	4.98
Growing Cattle (weighted average)	4.98	4.98
Sheep (weighted average)	5.00	5.00
Swine (weighted average)	14.00	14.00
Other Livestock (weighted average)	8.67	8.83
NH_3 from Agricultural Soils (kg/ha/year)	2.00	2.00
NH_3 from Alpine Area (kg/ha/year)	0.50	0.50
NO_x from applied fertilisers ($Frac_{NOXA}$)	0.55	0.55
NO_x from urine and dung N deposited on PR&P ($Frac_{NOXP}$)	0.55	0.55

Table 5-20 Overview of N pools and flows for calculating Indirect N_2O emission from managed soils (1990–2013). Complete time series by livestock subcategory level are provided in Annex 3 A3.3.

Nitrogen Pools and Flows		1990-2011									
		1990	1995	2000	2005	2006	2007	2008	2009	2010	2011
		t N/yr									
	Animals manure N applied to soils	115'195	106'426	90'885	86'285	86'510	86'650	88'540	87'613	87'509	87'220
	Commercial fertiliser	75'339	67'321	57'919	56'021	55'015	57'510	54'469	51'628	59'287	52'687
	Area of agricultural soils (ha)	1'066'981	1'080'226	1'072'492	1'065'118	1'065'199	1'060'242	1'058'100	1'055'648	1'051'748	1'051'866
	Alpine area (ha)	538'689	499'786	496'680	487'970	484'830	486'700	485'826	485'344	486'397	483'428
Deposition	Sum volatised N (NH_3 and NO_x)	39'829	36'888	30'518	28'612	28'764	29'341	29'049	27'973	27'793	27'457
	NH_3 emissions from commercial fertilisers	4'595	3'922	3'094	2'434	2'307	2'651	2'348	2'086	2'438	2'223
	NH_3 emissions from applied animal manure	31'034	28'805	22'981	21'619	21'896	22'119	22'140	21'383	20'848	20'779
	NH_3 emissions from pasture, range and paddock	674	717	1'110	1'267	1'274	1'279	1'280	1'250	1'221	1'210
	NH_3 emissions from agricultural soils	2'403	2'410	2'393	2'374	2'373	2'364	2'359	2'354	2'347	2'345
	NO_x emissions from commercial fertilisers	414	370	319	308	303	316	300	284	326	290
	NO_x emissions from applied animal manure	634	585	500	475	476	477	487	482	481	480
	NO_x emissions from PR&P	75	79	121	135	135	135	136	134	132	130
Leaching and run-off	Sum leaching and run-off	55'553	49'684	44'556	43'625	43'258	44'055	43'840	43'008	44'249	43'086
	Leaching and run-off from commercial fertilisers	17'649	15'157	12'618	12'205	11'986	12'529	11'867	11'248	12'916	11'478
	Leaching and run-off from applied animal manure	26'985	23'962	19'800	18'798	18'847	18'878	19'289	19'087	19'065	19'002
	Leaching and run-off from pasture, range and paddock	3'181	3'227	4'774	5'349	5'365	5'358	5'403	5'304	5'211	5'161
	Leaching and run-off from crop residues	7'737	7'337	7'362	7'272	7'059	7'290	7'280	7'367	7'056	7'444
	Leaching and run-off from mineralisation of SOM	1	1	2	1	1	1	1	1	1	1

Nitrogen Pools and Flows		2012-2013	
		2012	2013
		t N/yr	
	Animals manure N applied to soils	87'183	86'424
	Commercial fertiliser	50'987	49'487
	Area of agricultural soils (ha)	1'051'063	1'049'923
	Alpine area (ha)	481'394	479'760
Deposition	Sum volatised N (NH_3 and NO_x)	27'226	27'057
	NH_3 emissions from commercial fertilisers	2'034	2'059
	NH_3 emissions from applied animal manure	20'750	20'577
	NH_3 emissions from pasture, range and paddock	1'210	1'205
	NH_3 emissions from agricultural soils	2'343	2'340
	NO_x emissions from commercial fertilisers	280	272
	NO_x emissions from applied animal manure	480	475
	NO_x emissions from PR&P	130	129
Leaching and run-off	Sum leaching and run-off	42'487	41'680
	Leaching and run-off from commercial fertilisers	11'108	10'781
	Leaching and run-off from applied animal manure	18'994	18'828
	Leaching and run-off from pasture, range and paddock	5'154	5'126
	Leaching and run-off from crop residues	7'230	6'943
	Leaching and run-off from mineralisation of SOM	1	1

Figure 5-8 depicts the development of the most important activity data for Indirect N_2O emissions from managed soils. Ammonia emissions from application of commercial fertilisers declined mainly due to reduced fertiliser use and due to the decreasing share of fertilisers with high ammonia emission rates (i.e. urea and sewage sludge) (see chapter 5.5.2.2). Ammonia emissions from applied animal manure declined mainly due to declining livestock populations and hence due to the reductions of available manure N. The fraction of applied animal manure N that volatilises as NH_3 ($Frac_{GASMT}$) declined slightly and also contributed to the decreasing trend.

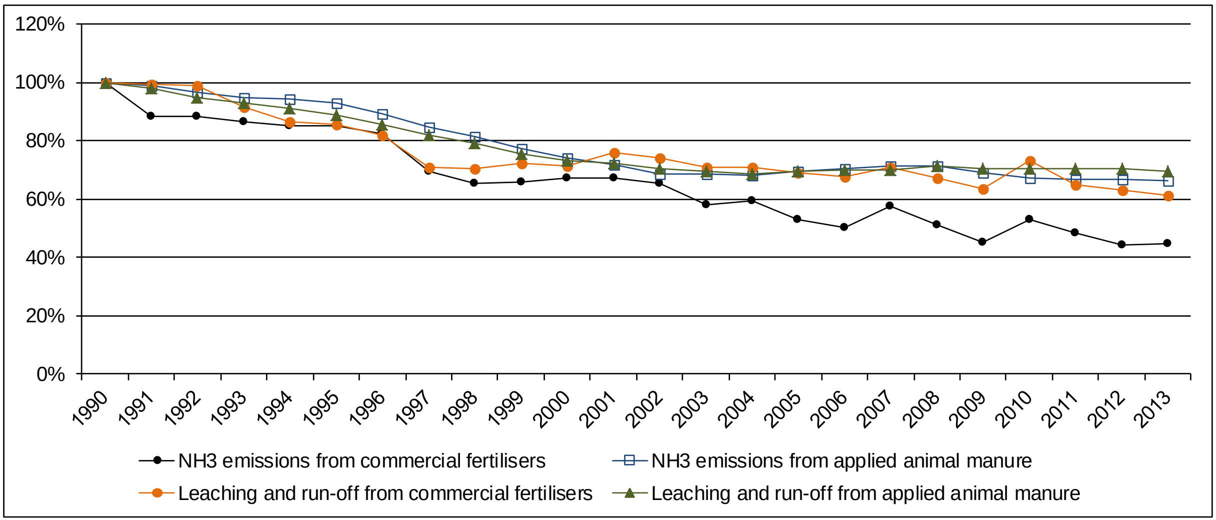


Figure 5-8 Relative development of the most important activity data for Indirect N_2O emissions from managed soils 1990-2013.

5.5.2.4 Indirect N_2O emissions from leaching and run-off from managed soils (3Db2)

N_2O emissions from leaching and run-off from managed soils were estimated based on equation 11.10 of the 2006 IPCC Guidelines:

$$N_2O_{(L)} - N = (F_{CN} + F_{AM} + F_{PRP} + F_{CR} + F_{SOM}) \bullet Frac_{LEACH-(H)} \bullet EF_5$$

$N_2O_{(L)}$–N = annual amount of N_2O–N produced from leaching and run-off of N additions to managed soils (kg N_2O–N/year)

F_{CN} = annual amount of commercial fertiliser N applied to soils (kg N/year)

F_{AM} = annual amount of managed animal manure N applied to soils (kg N/year)

F_{PRP} = annual amount of urine and dung N deposited by grazing animals (kg N/year)

F_{CR} = annual amount of N in crop residues, including N-fixing crops, returned to soils (kg N/year)

F_{SOM} = annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes of land use or management (kg N/year)

$Frac_{LEACH-(H)}$ = fraction of all N added to/mineralised in managed soils that is lost through leaching and runoff (kg N/kg of N additions)

EF_5 = emission factor for N_2O emissions from N leaching and run-off (kg N_2O–N/kg N leached and run-off)

Emission Factor

The emission factor for indirect N_2O emissions from leaching and run-off from managed soils is 0.0075 kg N_2O–N/kg N according to the 2006 IPCC guidelines.

Activity Data

For the calculation of N_2O emissions from leaching and run-off from managed soils, N-leaching from commercial fertilisers (including synthetic fertilisers, sewage sludge, compost, and liquid and solid digestates from biogas plants)(F_{CN}), managed animal manure N applied to soils (F_{AM}), urine and dung N deposited by grazing animals (F_{PRP}), N in crop residues returned to soils (F_{CR}) and N mineralised in mineral soils (F_{SOM}) were accounted for. The method for the assessment of the respective amounts of nitrogen is described in chapter 5.5.2.2 and numbers are contained in Table 5-18.

$Frac_{LEACH}$ was estimated for the year 2010 by dividing the available amount of nitrogen by the amount of nitrogen that is lost due to leaching and run-off in Switzerland according to model estimates of Hürdler et al. 2015. The respective loss rate is 21.8% for 2010. According to Spiess and Prasuhn (2006), it can be assumed that loss rates were somewhat higher in the early 1990s. Accordingly, a reduction in the nitrate loss rate of 7% was implemented between 1990 and 1999 leading to a $Frac_{LEACH}$ of 23.4% for 1990. The same loss rates have been applied to all nitrogen pools independent of their origin and composition. The resulting amount of nitrogen that is lost through leaching and run-off is given in Table 5-20.

Figure 5-8 depicts the development of the most important activity data for Indirect N_2O emissions from managed soils. Both leaching and run-off from commercial fertiliser and animal manure N declined during the inventory time period due to the reduced nitrogen inputs and the decreasing nitrate loss rates ($Frac_{LEACH}$).

5.5.2.5 NMVOC emissions

Estimation of NMVOC emissions of meadows and arable land is based on Spirig and Neftel (2002). VOC flows are estimated in Warneke et al. (2002) (for meadows) and König et al. (1995) (for arable land). Emissions were measured in a field trial in Austria (Karl et al. 2001).

5.5.3 Uncertainties and Time-Series Consistency

For the uncertainty analysis the input data from ART (2008a) were used and were updated with current activity and emission data as well as with new default uncertainties of the 2006 IPCC Guidelines. The arithmetic mean of the lower and upper bound uncertainty is used for activity data and for emission factors, resulting in combined Approach 1 uncertainties as shown in Table 5-21. For 3Da (Direct N_2O emissions – Fertilisers) the sub-positions 3Da 1, 2, 4, 5 and 7 were combined according to Approach 1 error propagation.

For the Approach 2 analysis, asymmetric probability distributions as well as possible correlations of input data were considered.

For further results also consult chapter 1.7.1.

Table 5-21 Uncertainties for 3D Agricultural soils 2013. (AD: Activity data; EF: Emission factor; CO: Combined).

Uncertainty 3D		Approach 1			Approach 2		
		AD	EF	CO	low	high	mean
		%			%		
Direct soil emissions	Fertilisers	15.0	135.0	135.8	-64	87	76
	Organic soils	29.4	137.5	140.6	-68	97	83
	Urine and dung deposited on PR&P	68.3	132.5	149.1	-68	114	91
Indirect soil emissions	Atmospheric deposition	39.6	240.0	243.2	-76	122	99
	Leaching and run-off	22.4	163.3	164.9	-77	102	90

The time series 1990–2013 are consistent, although the following issues should be considered:

- Input data from the AGRAMMON-model are available for the years 1990 and 1995 (expert judgement and literature) as well as for 2002, 2007 and 2010 (extensive surveys on approximatively 3000 farms). Values in-between the assessment years were interpolated linearly, whereas values beyond 2010 are kept constant and will be updated as new survey results become available.
- Estimated amounts of sewage sludge and compost are available for the years 1990, 1995, 2000, 2005, 2007 and 2010. Years in-between were interpolated linearly. Beyond 2010, the 2010 value was used and will be updated as further survey results become available.
- The emission factor for indirect N_2O emissions following volatilisation of NH_3 and NO_x from applied fertilisers and urine and dung excreted on PR&P varies according to varying land use as described in chapter 5.3.2.4.
- For more details on time-series consistency see Chapter 5.2.3 and 5.3.3.

5.5.4 Source-Specific QA/QC and Verification

General QA/QC measures are described in NIR chapter 1.2.3.

Since the CRF reporter was not available at the time of updating the EMIS data-base, the emissions from the EMIS data base were compared to data from last CRF submission tables (2014) for plausibility reasons.

All further category specific QA/QC activities are described in a separate document (ART 2013a). General information on agricultural structures and policies is provided and eventual differences between national and (IPCC) standard values are being analysed and discussed.

The original IULIA-model is described in Schmid et al. (2000). Despite the different assumptions of the IPCC method and the IULIA/AGRAMMON method, differences at the level of overall N_2O emissions are quite moderate. In a comparison of the 1996 N_2O inventory, IULIA estimates of the N_2O emissions from agriculture were approximately 15% lower than estimates based on the IPCC methods. Main differences between the IULIA/AGRAMMON method and IPCC are (Schmid et al. 2000: p. 74; Table 5-22):

- IULIA/AGRAMMON estimates lower nitrogen excretion per animal category, especially due to the lower excretions of young cattle (refer to chapter 5.3.2.5).
- Compared to the IPCC default method more manure is managed in liquid systems and less manure is excreted on pasture, range and paddock. Furthermore the manure management system distribution is not constant over the time series.

- The nitrogen inputs from crop residues (including nitrogen fixing crops on meadows and pasture) are higher by almost 200% as crop residues on permanent meadows and pastures are also considered. The consideration of crop residues from permanent grasslands is one of the major advantages of the method IULIA as grasslands represent approximatively two third of the agricultural area in Switzerland.
- The amount of losses to the atmosphere from animal manure N applied to soils and from urine and dung N deposited on pasture, range and paddock by grazing animals is 25% higher compared to IPCC.
- The amount of leaching (of manure nitrogen and of commercial fertilisers) is lower by almost 1/3 compared to IPCC.

Table 5-22 Comparison of N_2O emissions between the IPCC approach of Schmid et al. (2000), the original IULIA model and the current Swiss GHG-Inventory 2015.

Emission source		**Schmid et al. IPCC**	**Schmid et al. IULIA**	**Submission 2015**
		N_2O emissions in kt N		
$F_{SN/CN}$	Synthetic / commercial fertilisers	0.73	0.76	0.65
$AWMS_{LS}$	Liquid/slurry	0.10	0.08	0.00
$AWMS_{SS}$	Solid storage	0.48	0.80	0.16
$AWMS_{O}$	Other AWMS	0.06		0.05
PRP	Pasture, range and paddock manure	0.78	0.39	0.31
F_{AM}	Animal manure applied to soils	1.49	0.96	1.04
$F_{CR,AC}$	Crop residues from arable crops applied to soils	0.38	0.20	0.12
$F_{CR,MP}$	Crop residues from PR&P applied to soils		0.29	0.22
$F_{BF,AC}$	Biological fixation of arable crops	0.01	0.01	
$F_{BF,MP}$	Biological fixation on PR&P		0.40	
F_{OS}	Organic soils (i.e. histosols)	0.04	0.04	0.15
F_{DEP}	Atmospheric deposition	0.44	0.53	1.39
F_{LEACH}	Leaching and run-off	1.89	1.02	0.37
Total		6.39	5.49	4.46

The Swiss ammonium emission model AGRAMMON is documented in Kupper et al. (2013) and Agrammon (2010).

All relevant data needed for the calculation of direct and indirect nitrogen inputs to agricultural soils (e.g. F_{CN}, MS-distribution, $Frac_{GASF}$, N_{ex}, $Frac_{GASMT}$, F_{ON}, F_{CR}, $Frac_{LEACH}$) were checked for consistency and confidence and were compared (where possible) to IPCC default values, values of other countries as well as values in the literature. As one of the most important parameters, nitrogen excretion was analysed in more detail as described in Chapter 5.3.4.2.

For quality of livestock population data consult Chapter 5.2.4.

The estimate for the area of cultivated histosols in the agricultural sector is consistent with the estimates reported under cropland and grassland in the LULUCF sector. A literature study conducted by Leifeld et al. (2003) estimates 17'000 ± 5'000 ha which is close to the numbers reported in the LULUCF sector (18'100 ha on average).

According to Schmid et al. (2000: p.71) the IPCC default value for $Frac_{LEACH}$ is not representative for N application in Switzerland and would lead to a significant overestimation. While the default value is based on a global model which assumes that 30% of nitrogen from synthetic fertiliser and atmospheric deposition is reaching water bodies, the country-specific value is based on a very detailed model for the assessment of leaching and run-off in

Switzerland (Hürdler et al. 2015) that takes into account regional parameters such as topography, different crop species as well as fertiliser application levels.

N_2O emission factors were compared to values in the literature to ensure plausibility. Implied emission factors are similar to measured values from the literature representative for Swiss conditions (ART 2013a).

5.5.5 Source-Specific Recalculations

For recalculation of livestock numbers see chapter 5.2.5.

For recalculation of the nitrogen excretion rates of mature dairy cattle see chapter 5.3.5.

A general recalculation for the years 2011 and 2012 was carried out due to some updates of crop yield data from the Swiss Farmers Union (SBV 2014). The respective changes are only of minor importance for total emission estimates. Additionally, some new crop species were introduced to estimate nitrogen inputs from crop residues (millet, lupines, oil squash, oil hemp, oil flax, hops and medicinal plants and herbs). However, overall nitrogen inputs from crop residues increased on average by only 0.04%.

The nitrogen-flow-model was revised according to the 2006 IPCC Guidelines.

Emission factors for N_2O emissions from N inputs (EF_1) and N_2O emissions from urine and dung N deposited on pasture, range and paddock by grazing animals (EF_3) were adapted to the new IPCC default values (IPCC 2006).

The area of agricultural land and the alpine area used to estimate NH_3 volatilisation from the vegetation cover was slightly revised with negligible effects on overall emissions.

NO_x volatilisation was revised adopting more detailed literature values (Stehfest and Bouwman 2006).

The emission factor for indirect N_2O emissions from atmospheric deposition of N was revised. New country-specific estimates based on the studies of Bühlmann et al. (2015) and Bühlmann (2014) were adopted, increasing indirect N_2O emissions substantially.

$Frac_{LEACH}$ was recalculated due to new model estimates from Hürdler et al. (2015).

The emission factor for indirect N_2O emissions from leaching and run-off (EF_5) was adapted to the 2006 IPCC Guidelines. Accordingly the indirect N_2O emissions due to leaching and run-off on agricultural soils decreased substantially in the new inventory model.

General information on recalculations is provided in chapter 10.

5.5.6 Source-Specific Planned Improvements

The temporal development of $Frac_{LEACH}$ might be recalculated when new results from further modelling studies become available.

Further QA/QC checks of the new methodologies will be conducted and the respective documentation shall be updated.

5.6 Source Category 3E – Prescribed burning of savannahs

Burning of savannahs does not occur (NO) in Switzerland.

5.7 Source Category 3F – Field burning of agricultural residues

Field burning of agricultural residues does not occur (NO) in Switzerland.

Emissions from open burning of branches in agriculture and forestry have been reported here in the past. However, since branches in agriculture and forestry are burned only after being translocated from their place of origin, they are reported under sector 5 Waste in accordance to the EMEP guidebook 2009 (EMEP/EEA 2010). Accordingly, the emissions of this activity are reported under 5C Incineration and open burning of waste, chapter 7.4.

5.8 Source Category 3G – Liming

5.8.1 Source Category Description

CO_2 emission from Liming is not a key category.

Emissions from the application of lime ($Ca(CO_3)$) and dolomite ($CaMg(CO_3)_2$) to agricultural soils should be reported. However, dolomite is probably applied only in small quantities and the available data do not allow differentiation between $Ca(CO_3)$ and $CaMg(CO_3)_2$.

The emissions due to liming of agricultural soils range from 22.6 to 32.6 kt CO_2 per year.

5.8.2 Methodological Issues

A simple Tier 1 approach was adopted using estimated amounts of lime applied and IPCC default emission factors.

5.8.2.1 Emission Factor

The availability of a country-specific emission factor for agricultural lime application was investigated, but no domestic measurement data could be found. Consequently, the IPCC default carbon conversion factor for carbonate containing lime of 0.12 t C per t $Ca(CO_3)$ was used (IPCC 2006).

5.8.2.2 Activity Data

The total annual amount of lime applied to agricultural soils is between 51’300 Mg (1990) and 74'050 Mg (2008-2013). It was estimated by Agroscope in 2009 for the period 1990-2008. For 2009–2013 the same value as for 2008 was used: An inquiry in 2013 including the most important production and trading companies of lime products suggests that the consumption of limestone remained constant in this period (Agroscope 2014a).

5.8.3 Uncertainties and Time-Series Consistency

The amount of total lime applied in agriculture is mainly based on expert judgement; the resulting number is uncertain. A relative uncertainty of ± 40% was used as an approximation (Agroscope 2014a). For the emission factor of lime a lower uncertainty of ± 5% was chosen, because it is simply a chemical process. The combined Approach 1 uncertainty is thus ±40.3%. Approach 2 uncertainties do not differ significantly from Approach 1 uncertainties.

For further results also consult chapter 1.7.1.

Consistency: Time series for 3G Liming are all considered consistent.

5.8.4 Source-Specific QA/QC and Verification

General QA/QC measures are described in NIR chapter 1.2.3.

Since the CRF reporter was not available at the time of updating the EMIS data-base, the emissions from the EMIS data-base were compared to data from last CRF submission tables (2014) for plausibility reasons.

No further source specific quality assurance activities were conducted.

5.8.5 Source-Specific Recalculations

No recalculations were conducted.

General information on recalculations is provided in chapter 10.

5.8.6 Source-Specific Planned Improvements

There are no further planned improvements in this area at the moment.

5.9 Source Category 3H – Urea application

5.9.1 Source Category Description

CO_2 emission from Urea application is not a key category.

Adding urea to soils during fertilisation leads to a loss of CO_2 that was extracted from the atmosphere and fixed during the industrial production process of the fertilizer. Emissions in Switzerland range from 8.7 to 26.7 kt CO_2 per year with a general decreasing trend from 1990 to 2013.

5.9.2 Methodological Issues

A simple Tier 1 approach was adopted using estimated amounts of urea applied and IPCC default emission factors.

5.9.2.1 Emission Factor

No country-specific emission factors are available. Consequently, the IPCC default emission factor of 0.20 t of C per t of urea was applied.

5.9.2.2 Activity Data

The amount of urea applied to agricultural soils was obtained from Agricura (2014). Fertiliser statistics are based on sales statistics by the compulsory storekeepers of fertilisers (Pflichtlagerhalter) and small importers. Agricura conducts plausibility checks with import-data received by the Directorate General of Customs (Oberzolldirektion).

5.9.3 Uncertainties and Time-Series Consistency

An uncertainty of ±5% for the activity data was estimated according to ART (2008a). An uncertainty of ±5% was assumed for the emission factor since it is simply a chemical process. The combined Approach 1 uncertainty is hence ±7.1%. Approach 2 uncertainties do not differ significantly from Approach 1 uncertainties.

For further results also consult chapter 1.7.1.

Consistency: Time series for 3H Urea Application are all considered consistent.

5.9.4 Source-Specific QA/QC and Verification

General QA/QC measures are described in NIR chapter 1.2.3.

No further source specific quality assurance activities were conducted.

5.9.5 Source-Specific Recalculations

No recalculations were conducted.

General information on recalculations is provided in chapter 10.

5.9.6 Source-Specific Planned Improvements

There are no further planned improvements in this area at the moment.

6 LULUCF

6.1 Overview of LULUCF

6.1.1 Methodology

Chapter 6 presents estimates of greenhouse gas emissions by sources and removals by sinks from land use, land-use change and forestry (LULUCF). The sector LULUCF also includes emissions and removals from the carbon pool in harvested wood products (HWP). Data acquisition and calculations are based on the Guidelines for National Greenhouse Gas Inventories (IPCC 2006), Volume 4 "Agriculture, Forestry and Other Land Use" (AFOLU). They are completed by country-specific methodologies.

The land areas in the period 1990-2013 are represented by geographically explicit land-use data with a resolution of one hectare (following approach 3 for representing land areas; IPCC 2006). Direct and repeated assessment of land use with full spatial coverage also enables to calculate spatially explicit land-use change matrices. In 2004, the Swiss Land Use Statistics AREA was launched. Simultaneously, aerial photos from two earlier Swiss Land Use Statistics (1979/85 and 1992/97) were re-evaluated, applying the same approach. The AREA survey had been completed in 2013 and the interpretation of the entire Swiss territory is available for three time slices.

The six main land-use categories required by IPCC (2006) are: A. Forest Land, B. Cropland, C. Grassland, D. Wetlands, E. Settlements and F. Other Land. These categories were divided in 18 sub-divisions of land use. A further spatial stratification reflects the criteria “altitude” (3 zones),”geomorphologic and climatic conditions” (adopting the five production regions of the National Forest Inventory; NFI) and ”soil type” (mineral, organic).

Country-specific emission factors and carbon stocks for Forest Land were derived from four Swiss National Forest Inventories (NFI 1 – NFI 4b), which had been finalised in 1985, 1995, 2006 and 2013, respectively. The inventories comprehended ca. 3'400 (2013), 6'500 (1995, 2006) and 11'000 (1985) terrestrial sampling plots (see Table 6-11), where biomass stock, growth, harvesting and mortality had been measured.

For the remaining land-use categories, carbon stocks and GHG emissions and removals were derived from particular research activities, domestic surveys and measurements in the fields of agriculture (cropland, grassland) and nature conservation (wetlands). Partially, also IPCC default values and expert estimates were used.

6.1.2 Emissions and Removals

Table 6-1 and Figure 6-1 summarize the CO_2 emissions and removals as a result of carbon losses and gains for the years 1990-2013. The total net emissions and removals of CO_2 from 1990 to 2013 vary between -3'915 kt (1993) and 964 kt (2001).

Table 6-1 and Figure 6-1 show a breakdown of Switzerland’s CO_2 balance. Five components are differentiated:

- Gains in carbon stock of living biomass on all land uses and due to land-use changes; it represents the largest sink of carbon.
- Losses in carbon stock of living biomass on all land uses and due to land-use changes; it represents the largest source of carbon. The highest losses were observed in the years following a heavy storm with windfall in December 1999.
- Net carbon stock changes in dead organic matter (DOM; consisting of dead wood and litter) on forest land remaining forest land as well as on forest land converted to non-forest land: it represents a sink of carbon in most years.
- Net carbon stock changes (1) in soils due to the use of soils (especially of organic soils) and due to land-use changes, and (2) by wildfires. In the period under investigation this accumulative component persistently represents a source of carbon.
- Net carbon stock changes in harvested wood products (HWP). In the period under investigation this component persistently represents a sink of carbon, i.e. the carbon stock stored in wood products was increasing.

The largest part of gains and losses in carbon stocks of biomass occurs in forests, where growth of biomass exceeds the harvesting and mortality rate, except for the years 2000-2002. Overall, the LULUCF sector was a sink of -2’188 kt CO_2 on the average between 1990 and 2013 (see Table 6-1 and Figure 6-2).

Table 6-1 Switzerland's CO_2 emissions and removals (kt) of sector 4 (LULUCF) 1990-2013. Positive values refer to emissions; negative values refer to removals. In this data set, emissions of CH_4 and N_2O are not included.

LULUCF	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt CO_2									
Gains of living biomass	-12'718	-12'647	-12'841	-12'793	-12'250	-12'971	-13'015	-12'960	-12'530	-12'266
Losses of living biomass	9'937	10'055	10'069	8'953	8'962	9'074	9'871	9'744	9'973	10'468
Net change in dead organic matter	189	-76	-45	-158	165	32	-264	-649	-913	-824
Net change in organic and mineral soils and wildfires	735	713	709	712	728	735	737	765	753	749
LULUCF (excluding HWP)	-1857	-1955	-2108	-3286	-2396	-3130	-2672	-3100	-2717	-1874
Net change in harvested wood products (HWP)	-1'224	-939	-775	-632	-480	-566	-403	-321	-430	-486
Total LULUCF	-3081	-2894	-2883	-3919	-2876	-3696	-3074	-3421	-3146	-2359

LULUCF	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt CO_2									
Gains of living biomass	-13'035	-12'332	-12'688	-12'461	-13'356	-12'773	-12'379	-13'433	-13'117	-13'160
Losses of living biomass	13'346	13'742	13'584	11'123	10'784	11'229	11'236	11'603	11'593	11'301
Net change in dead organic matter	-763	-625	-442	-631	-629	-929	-698	-445	-215	-242
Net change in organic and mineral soils and wildfires	750	751	761	765	754	778	784	779	747	730
LULUCF (excluding HWP)	299	1536	1214	-1204	-2448	-1695	-1057	-1496	-992	-1371
Net change in harvested wood products (HWP)	-838	-582	-454	-449	-644	-772	-633	-742	-525	-479
Total LULUCF	-539	954	761	-1652	-3092	-2467	-1690	-2237	-1517	-1850

LULUCF	2010	2011	2012	2013	Mean
	kt CO_2				
Gains of living biomass	-12'806	-13'736	-12'803	-12'648	-12'822
Losses of living biomass	11'088	11'040	10'936	11'181	10'870
Net change in dead organic matter	-613	-463	-403	-251	-412
Net change in organic and mineral soils and wildfires	741	746	744	747	746
LULUCF (excluding HWP)	-1590	-2414	-1525	-972	-1'617
Net change in harvested wood products (HWP)	-510	-370	-300	-158	-571
Total LULUCF	-2099	-2783	-1825	-1130	-2'188

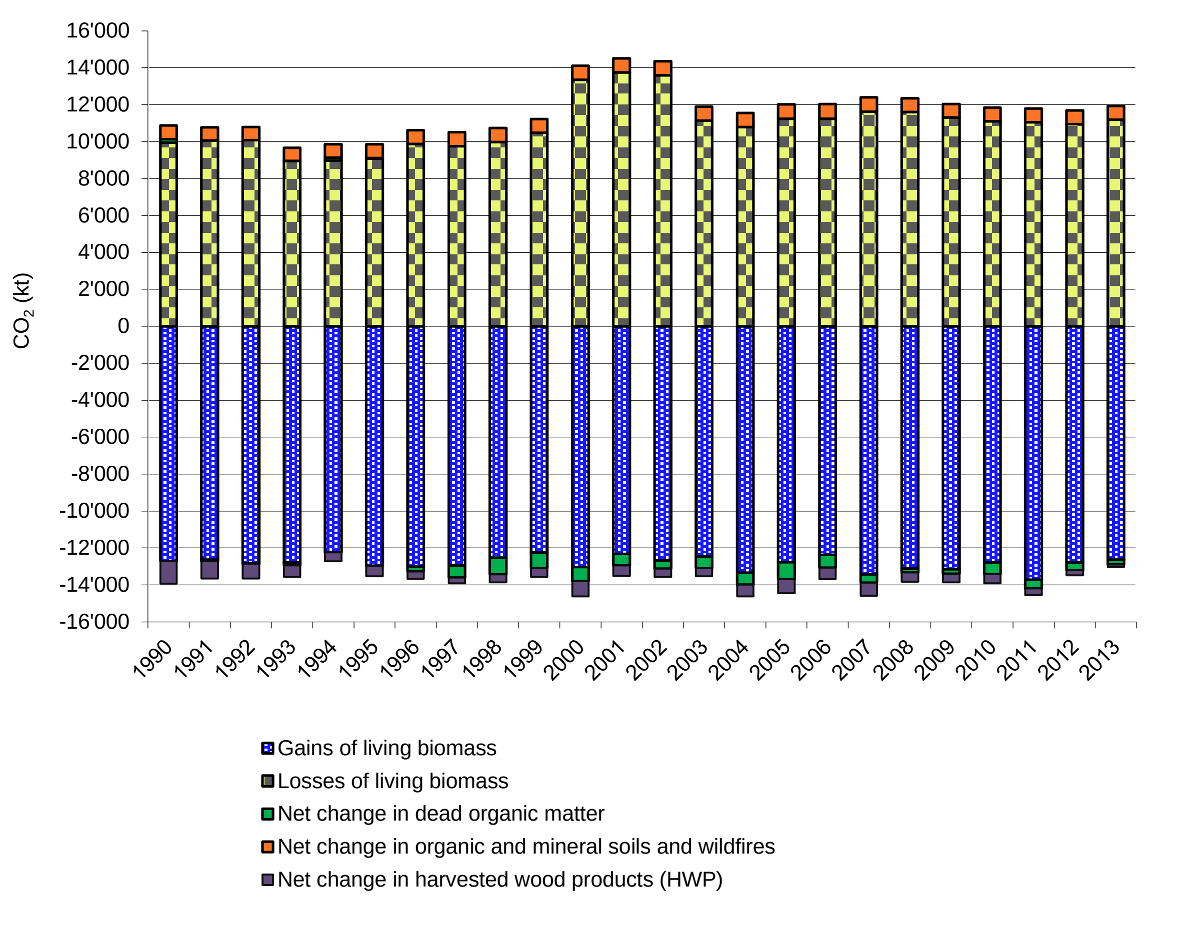


Figure 6-1 (i) CO_2 removals due to the gain (growth) of living biomass, (ii) CO_2 emissions due to the loss (harvest and mortality) of living biomass, (iii) net CO_2 emissions and removals due to changes in dead organic matter, (iv) net CO_2 emissions from soils and wildfires, and (v) net CO_2 removals from harvested wood products, 1990–2013.

The non-CO_2 emissions associated with land use, land-use change and forestry are relatively small. Between 1990 and 2013 annual CH_4 emissions add up to less than 1.81 kt, and annual N_2O emissions equal at maximum 0.29 kt. The emissions arise from drained organic soils (N_2O; CRF-table 4(II)), flooded land/reservoirs (CH_4; CRF-table 4(II)), soil disturbance and mineralisation associated with land-conversions (N_2O; CRF-table 4(III)), nitrogen leaching and run-off on non-agricultural soils (indirect N_2O emissions; CRF-table 4(IV)), and wildfires on forest land and grassland (CH_4 and N_2O; CRF-table 4(V)). The calculation methods are based on default procedures of IPCC (2006, Volume 4).

Figure 6-2 shows the resulting net GHG emissions and removals of category 4 LULUCF 1990–2013 including all CO_2 and non-CO_2 fluxes. Further representations of LULUCF CO_2 eq data can be found in Chapter 2 “Trends in Greenhouse Gas Emissions and Removals”.

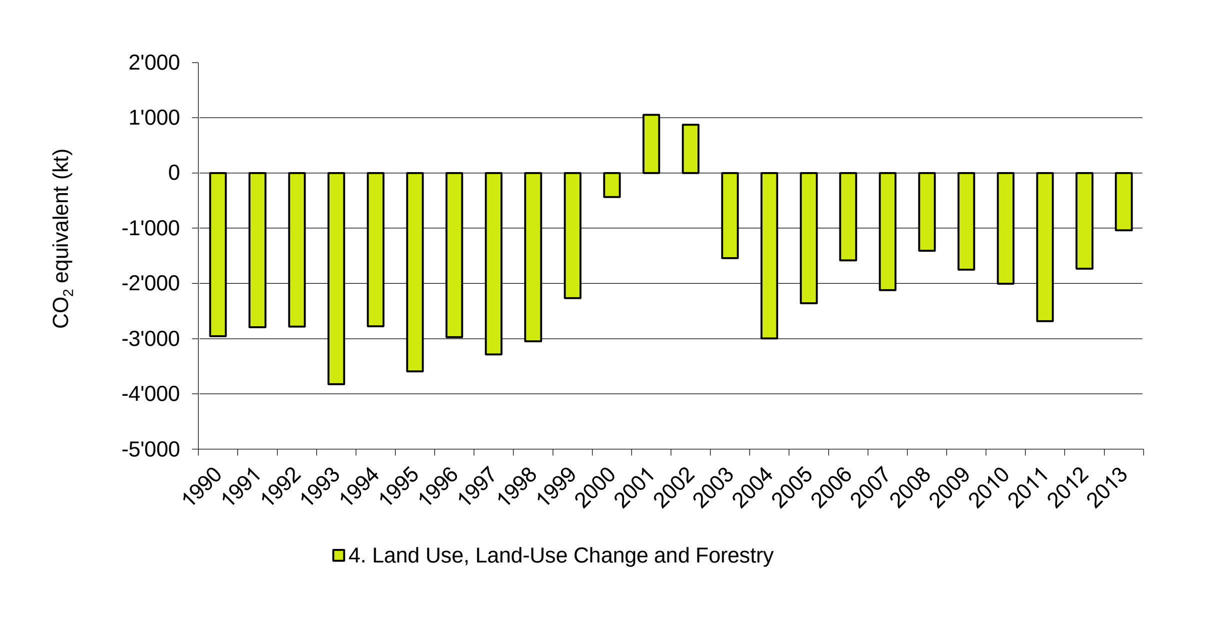


Figure 6-2 Switzerland's net GHG emissions and removals of category 4 Land Use, Land-Use Change and Forestry, 1990–2013 (in kt CO_2 eq). Positive values refer to emissions, negative values refer to removals.

6.1.3 Approach for Calculating Carbon Emissions and Removals

6.1.3.1 Work Steps

The selected procedure for calculating carbon emissions and removals in the LULUCF sector corresponds to a Tier 2 approach as described by IPCC 2006 (Volume 4, Chapter 3). It can be summarised as follows:

- Define land use categories and sub-divisions with respect to available land-use data (see Table 6-2). For the present study, combination categories (CC) were defined on the basis of the AREA land-use and land-cover categories (Table 6-6; SFSO 2006a).
- Define criteria and collect data for the spatial stratification of the land-use categories.
- Measure or estimate the carbon stocks and carbon stock changes for each spatial stratum of the land-use categories.
- Calculate the land use and the land-use change matrix in each spatial stratum.
- Calculate the carbon stock changes in living biomass (deltaCl), in dead organic matter (deltaCd) and in soil (deltaCs) for all cells of the land-use change matrix.
- Finally, aggregate the results by summarising the carbon stock changes over land-use categories and strata according to the level of disaggregation displayed in the CRF-tables.

Table 6-2 Land-use categories used in this report (combination categories CC): 6 main land-use categories (identical to the UNFCCC land-use categories) and 18 sub-divisions. Additionally, descriptive remarks, abbreviations used in the CRF-tables, and CC codes are given. For a detailed definition of the combination categories see Table 6-6 and SFSO (2006a).

CC Main category	**CC Sub-division**	**Remarks**	**Terminology in CRF tables**	**CC code**
A. Forest Land	Afforestations	areas converted to forest by active measures, e.g. planting	afforestation	11
	Productive Forest	dense and open forest meeting the criteria of forest land	productive	12
	Unproductive Forest	brush forest and forest on unproductive areas meeting the criteria of forest land	unproductive	13
B. Cropland		arable and tillage land (annual crops and leys in arable rotations)		21
C. Grassland	Permanent Grassland	meadows, pastures (low-land and alpine)	permanent	31
	Shrub Vegetation	agricultural and unproductive areas predominantly covered by shrubs	woody, shrub	32
	Vineyards, Low-Stem Orchards, Tree Nurseries	perennial agricultural plants with woody biomass (no trees)	woody, vine	33
	Copse	agricultural and unproductive areas covered by perennial woody biomass including trees	woody, copse	34
	Orchards	permanent grassland with fruit trees	woody, orchard	35
	Stony Grassland	grass, herbs and shrubs on stony surfaces	unproductive, stony	36
	Unproductive Grassland	unmanaged grass vegetation	unproductive	37
D. Wetlands	Surface Waters	lakes and rivers	other wetlands	41
	Unproductive Wetland	reed, unmanaged wetland	other wetlands	42
E. Settlements	Buildings and Constructions	areas without vegetation such as houses, roads, construction sites, dumps	building	51
	Herbaceous Biomass in Settlements	areas with low vegetation, e.g. lawns	herb	52
	Shrubs in Settlements	areas with perennial woody biomass (no trees)	shrub	53
	Trees in Settlements	areas with perennial woody biomass including trees	tree	54
F. Other Land		areas without soil and vegetation: rocks, sand, scree, glaciers		61

6.1.3.2 Calculating Carbon Stock Changes

For calculating carbon stock changes, the following input parameters (mean values per hectare) must be quantified for all combination categories (CC) and spatial strata (i):

$stockC_{l,i,CC}$	carbon stock in living biomass (t C ha^{-1})
$stockC_{d,i,CC}$	carbon stock in dead wood (t C ha^{-1})
$stockC_{h,i,CC}$	carbon stock litter (organic soil horizons) (t C ha^{-1})
$stockC_{s,i,CC}$	carbon stock in soil (t C ha^{-1})
$gainC_{l,i,CC}$	annual gain (growth) of carbon in living biomass (t C ha^{-1} yr^{-1})
$lossC_{l,i,CC}$	annual loss (harvesting and mortality) of carbon in living biomass (t C ha^{-1} yr^{-1})
$changeC_{d,i,CC}$	annual net carbon stock change in dead wood (t C ha^{-1} yr^{-1})
$changeC_{h,,i,CC}$	annual net carbon stock change in litter (t C ha^{-1} yr^{-1})
$changeC_{s,i,CC}$	annual net carbon stock change in soil (t C ha^{-1} yr^{-1})

In the CRF tables reporting non-forest land-use categories under the UNFCCC, the carbon stocks and carbon stock changes of litter and dead wood are merged into "dead organic matter" (DOM):

$$stockC_{dom,i,CC} = stockC_{d,i,CC} + stockC_{h,i,CC}$$

$$changeC_{dom,i,CC} = changeC_{d,i,CC} + changeC_{h,i,CC}$$

On this basis, the total carbon fluxes (t C yr^{-1}) in living biomass ($deltaC_l$), in dead wood ($deltaC_d$), in litter ($deltaC_h$) and in soils ($deltaC_s$) are calculated for all cells of the land-use change matrix. Each cell is characterized by a land-use category before the reporting year (b), a land-use category at the end of the reporting year (a), and the area of converted land within the spatial stratum (i). This approach includes cases without any land-use change (a = b).

Equations 6.1 - 6.8 show, according to the AFOLU-Guidelines (IPCC 2006, Volume 4), two approaches and their application for calculating carbon emissions and removals: (1) the gain-loss approach (Equation 2.4; IPCC 2006, Volume 4) and (2) the stock-difference approach (Equation 2.5; IPCC 2006, Volume 4).

The gain-loss approach is used in cases of no land-use change. It is also applied on land after conversion for calculating continuous changes in living biomass, dead wood, litter and soils. The stock-difference approach takes into account the stock changes due to conversion of land use (difference of the stocks before and after the conversion).

The gain-loss approach is defined as:

$$deltaC_{l,i,ba} = (gainC_{l,i,a} – lossC_{l,i,a}) * A_{i,ba} \quad (6.1)$$

$$deltaC_{d,i,ba} = changeC_{d,i,a} * A_{i,ba} \quad (6.2)$$

$$deltaC_{h,i,ba} = changeC_{h,i,a} * A_{i,ba} \quad (6.3)$$

$$deltaC_{s,i,ba} = changeC_{s,i,a} * A_{i,ba} \tag{6.4}$$

The stock-difference approach is defined as:

$$deltaC_{l,i,ba} = [(stockC_{l,i,a} – stockC_{l,i,b}) / CT] * A_{i,ba} \tag{6.5}$$

$$deltaC_{d,i,ba} = [(stockC_{d,i,a} – stockC_{d,i,b}) / CT] * A_{i,ba} \tag{6.6}$$

$$deltaC_{h,i,ba} = [(stockC_{h,i,a} – stockC_{h,i,b}) / CT] * A_{i,ba} \tag{6.7}$$

$$deltaC_{s,i,ba} = [(stockC_{s,i,a} – stockC_{s,i,b}) / CT] * A_{i,ba} \tag{6.8}$$

where:

a	land-use category after conversion (CC = a)
b	land-use category before conversion (CC = b)
ba	land use conversion from b to a
i	spatial stratum
$A_{i,ba}$	area of land (ha) converted from b to a in the spatial stratum i (activity data from the land-use change matrix)
CT	conversion time (yr), see Chapter 6.1.3.3

Table 6-3 pinpoints which approach is used for calculating the carbon fluxes for the various types of land-use conversion and carbon pools (living biomass, dead wood/litter and soil): The gain-loss approach is generally used for smooth transitions, e.g. the growth of living biomass on land converted to forest land. The stock-difference approach is used for quick changes following discrete events (e.g. loss of biomass by deforestation, CT = 1 year) as well as slow processes such as the change in soil carbon content (CT = 20 years, see Chapter 6.1.3.3).

For the conversions between different forest combination categories the approach is chosen in such a way that potential carbon losses cannot be underestimated: e.g. for CC12 to CC13 stock-difference is used, for CC13 to CC12 gain-loss is used, see Table 6-3.

In case of land-use changes involving "Buildings and Constructions" (CC51), 50% of the difference between carbon stocks before and after the conversion is reported as a source or sink, respectively; for a detailed documentation see Chapter 6.8.2.2.

Table 6-3 Calculation approach (gain-loss or stock-difference) and conversion time periods (CT, years) applied for different land-use changes and carbon pools. KP = corresponding activity under the Kyoto Protocol; NF = non-forest category. Combination categories CC11 to CC61 are introduced in Table 6-2.

Change in main land-use category or sub-division	Living biomass	Deadwood, Litter	Soil	Remarks
no change in category KP and UNFCCC	gain-loss	gain-loss	gain-loss	
CC13 to CC12 UNFCCC: 4A1 KP: forest management	gain-loss	stock-diff., 20	stock-diff., 20	
CC12 to CC13 UNFCCC: 4A1 KP: forest management	stock-diff., 20	stock-diff., 20	stock-diff., 20	
CC11 to CC12 UNFCCC: 4A1 KP: afforestation >20 years	gain-loss	gain-loss	gain-loss	
change to CC11 UNFCCC: 4A2 KP: afforestation ≤20 years	gain-loss	stock-diff., 20	stock-diff., 20	Dead organic matter is 0 in CC11 and in NF; directly human-induced
NF to CC12/CC13 UNFCCC: 4A2 KP: forest management	gain-loss	stock-diff., 20	stock-diff., 20	
change to CC51 UNFCCC: 4E2 KP: deforestation	stock-diff., 1	stock-diff., 1	stock-diff., 20	Buildings/constructions; soil: carbon stock reduced by 50%
change to CC52-54 UNFCCC: 4E2	stock-diff., 1	stock-diff., 1	stock-diff., 20	Unsealed settlement areas
change to CC21 UNFCCC: 4B2	stock-diff., 1	stock-diff., 1	stock-diff., 20	Cropland
change to CC31-37 UNFCCC: 4C2	stock-diff., 1	stock-diff., 1	stock-diff., 20	Grassland
change to CC41 UNFCCC: 4D2	stock-diff., 1	stock-diff., 1	stock-diff., 1	Surface water
change to CC42 UNFCCC: 4D2	stock-diff., 1	stock-diff., 1	stock-diff., 20	Unproductive wetland
change to CC61 UNFCCC: 4F2	stock-diff., 1	stock-diff., 1	stock-diff., 20	Other land

6.1.3.3 Considering the Conversion Time (CT)

Changes in the soil carbon stock – this is also true for the increase of woody biomass – as a result of land-use changes are slow processes that might take decades. Therefore, IPCC (2006, Volume 4/Chapter 2) suggests implementing a conversion time (CT). Following the IPCC default value (CT = 20 years), carbon emissions or removals due to a soil carbon stock difference (stockCs,i,a – stockCs,i,b) do not occur in one year but are distributed evenly over the 20 years following the land-use conversion.

A conversion time of 20 years has been applied to all soil carbon stock changes (except land converted to surface water). Accordingly, the CRF-tables 4A2, 4B2, 4C2, 4D2, 4E2 and 4F2 contain the cumulative area remaining in the respective category in the reporting year.

The land-use category Afforestations (CC11) is inherently a transitional category by definition in the land-use survey. Areas converted to afforestations are reported in the CRF-table 4A2 with the same conversion time as for other forest sub-categories (20 years). However, after 20 years, afforestations remaining afforestations (according to the land-use survey) are reported in CRF-table 4A1 and are merged with productive forests (CC12).

Table 6-3 summarises the conversion times applied to carbon stock changes in living biomass, in dead organic matter, and in soils for all types of land-use changes.

There is no consistent data sources on land-use changes before 1990, but it is well known (ARE/SAEFL 2001, FOEN 2014h) that the main trends of the Swiss land-use dynamics (e.g. increase of forests and settlements) did arise before 1970. Therefore, it was assumed that between 1971 and 1989 the annual rate of all land-use changes was the same as in 1990. Based on this assumption it has been possible to produce the land-use data required for the consideration of the conversion time in that period and to consider it in the years 1990 to 2009 in accordance with the 20 years conversion period.

6.1.3.4 Displaying Results in the Common Reporting Format (CRF)

In the CRF-tables 4A to 4F, a part of the combination categories (CC) and associated spatial strata are shown at an aggregated level for optimal documentation and overview. The values of deltaC are accordingly summarised. Positive values of $deltaC_{l,i,ba}$ are inserted in the column "Gains" and negative values in the column "Losses", respectively. The values of $deltaC_{d,i,ba}$ and $deltaC_{s,i,ba}$ are inserted in column "Net carbon stock change in dead organic matter" and "Net carbon stock change in soils", respectively.

The CRF-tables 4A to 4F are subdivided in two parts: (1) X Land remaining X Land and (2) Land converted to X Land. Changes of areas from one combination category to another within the same main land-use category are reported in part (1) of the CRF tables. For example, the area of "shrub vegetation" (CC32) converted to "permanent grassland" (CC31) would be reported in CRF-table 4C1 in the sub-division "permanent". As CC31 and CC32 do have different carbon stocks in biomass, a carbon stock change would be calculated according to the equations presented in Chapter 6.1.3.2.

6.1.4 Carbon Stocks, Emission Factors, and Net Changes at a Glance

Table 6-4 lists all values of carbon stocks, gains, losses and net changes of carbon specified for combination category (CC) and associated spatial strata for the year 1990. These values remain constant during the period 1990-2013 with the following exceptions (highlighted cells):

- Carbon stock, gain and loss of living biomass, carbon stock and net change in dead organic matter (dead wood and litter) as well as net change in mineral soils of productive forest (CC12): Deduction and values of the annually changing data of CC12 are described in Chapters 6.4.2.6, 6.4.2.7 and 6.4.2.8.
- Carbon stock, gain and loss of living biomass of cropland (CC21): Annual data of CC21 are listed in Chapter 6.5.2.

The deduction of the individual carbon stocks and emission factors is explained in detail in the Chapters 6.4 to 6.10.

Table 6-4 Carbon stocks and changes in living biomass, in dead wood, in litter and in soils for the combination categories (CC), stratified for altitude, NFI region, and soil type. The values are valid for the period 1990-2013 with the exception of the values in the highlighted cells, which change annually (numbers given here are for the year 1990); cf. main text.

land-use code CC	NFI region	altitude zone z	carbon stock in living biomass (stockCl,i)	carbon stock in dead wood (stockCd,i)	carbon stock in litter (stockCh,i)	carbon stock in mineral soil (stockCs,i)	carbon stock in organic soil (stockCs,i)	gain of living biomass (gainCl,i)	loss of living biomass (lossCl,i)	net change in dead wood (changeCd,i)	net change in litter (changeCh,i)	net change in mineral soil (changeCs,i)	net change in organic soil (changeCs,i)
	Strata		**[t C ha^{-1}]**					**[t C ha^{-1} yr^{-1}]**					
11 Afforestations	1	1	7.84	0	0	82.65	240	1.63	0	0	0	0	-2.6
	1	2	4.30	0	0	102.03	240	1.09	0	0	0	0	-2.6
	1	3	1.61	0	0	121.34	240	0.57	0	0	0	0	-2.6
	2	1	7.84	0	0	55.40	240	1.63	0	0	0	0	-2.6
	2	2	4.30	0	0	62.12	240	1.09	0	0	0	0	-2.6
	2	3	1.61	0	0	122.00	240	0.57	0	0	0	0	-2.6
	3	1	7.84	0	0	66.10	240	1.63	0	0	0	0	-2.6
	3	2	4.30	0	0	75.91	240	1.09	0	0	0	0	-2.6
	3	3	1.61	0	0	95.78	240	0.57	0	0	0	0	-2.6
	4	1	7.84	0	0	66.47	240	1.63	0	0	0	0	-2.6
	4	2	4.30	0	0	74.39	240	1.09	0	0	0	0	-2.6
	4	3	1.61	0	0	69.48	240	0.57	0	0	0	0	-2.6
	5	1	7.84	0	0	102.37	240	1.63	0	0	0	0	-2.6
	5	2	4.30	0	0	108.99	240	1.09	0	0	0	0	-2.6
	5	3	1.61	0	0	107.08	240	0.57	0	0	0	0	-2.6
12 Productive forest	1	1	126.87	5.84	9.51	82.65	240	3.60	-2.41	-0.01	-0.08	0.00	-2.6
	1	2	124.88	6.08	7.53	102.03	240	3.21	-2.27	-0.05	-0.08	0.00	-2.6
	1	3	84.73	6.51	7.76	121.34	240	1.95	-1.34	0.04	-0.26	0.00	-2.6
	2	1	134.18	9.22	8.70	55.40	240	4.63	-4.13	-0.07	-0.13	0.00	-2.6
	2	2	146.77	8.99	11.42	62.12	240	4.63	-3.93	-0.05	-0.02	0.00	-2.6
	2	3	101.21	8.99	11.42	122.00	240	1.60	-0.86	-0.05	-0.02	0.00	-2.6
	3	1	135.06	10.36	7.51	66.10	240	4.56	-3.04	0.29	0.25	0.00	-2.6
	3	2	147.43	9.46	16.29	75.91	240	4.15	-3.06	0.00	-0.10	0.00	-2.6
	3	3	119.32	8.18	26.21	95.78	240	2.48	-2.11	-0.20	-0.14	0.00	-2.6
	4	1	94.81	8.12	3.15	66.47	240	3.24	-2.71	0.28	-0.03	0.00	-2.6
	4	2	104.42	8.05	19.99	74.39	240	2.49	-1.81	-0.09	-0.08	0.00	-2.6
	4	3	96.41	7.91	33.37	69.48	240	1.81	-1.62	0.01	-0.04	0.00	-2.6
	5	1	70.67	2.99	8.22	102.37	240	2.74	-1.01	-0.13	-0.27	0.00	-2.6
	5	2	76.70	3.29	11.03	108.99	240	2.20	-0.71	0.09	-0.29	0.00	-2.6
	5	3	76.70	3.01	30.77	107.08	240	1.61	-0.48	-0.05	0.04	0.00	-2.6
13 Unproductive forest	1	1	38.53	0.00	9.51	82.65	240	0	0	0	0	0	-2.6
	1	2	51.10	0.00	7.53	102.03	240	0	0	0	0	0	-2.6
	1	3	51.34	0.00	7.76	121.34	240	0	0	0	0	0	-2.6
	2	1	20.45	0.00	8.70	55.40	240	0	0	0	0	0	-2.6
	2	2	35.83	0.00	11.42	62.12	240	0	0	0	0	0	-2.6
	2	3	51.33	0.00	11.42	122.00	240	0	0	0	0	0	-2.6
	3	1	20.45	0.00	7.51	66.10	240	0	0	0	0	0	-2.6
	3	2	47.53	0.00	16.29	75.91	240	0	0	0	0	0	-2.6
	3	3	42.36	0.00	26.21	95.78	240	0	0	0	0	0	-2.6
	4	1	21.60	0.00	3.15	66.47	240	0	0	0	0	0	-2.6
	4	2	31.48	0.00	19.99	74.39	240	0	0	0	0	0	-2.6
	4	3	29.88	0.00	33.37	69.48	240	0	0	0	0	0	-2.6
	5	1	20.83	0.00	8.22	102.37	240	0	0	0	0	0	-2.6
	5	2	23.82	0.00	11.03	108.99	240	0	0	0	0	0	-2.6
	5	3	24.35	0.00	30.77	107.08	240	0	0	0	0	0	-2.6

(Table 6-4 continued)

land-use code CC	NFI region	altitude zone z	carbon stock in living biomass (stockCl,i)	carbon stock in dead wood (stockCd,i)	carbon stock in litter (stockCh,i)	carbon stock in mineral soil (stockCs,i)	carbon stock in organic soil (stockCs,i)	gain of living biomass (gainCl,i)	loss of living biomass (lossCl,i)	net change in dead wood (changeCd,i)	net change in litter (changeCh,i)	net change in mineral soil (changeCs,i)	net change in organic soil (changeCs,i)
	Strata		[t C ha^{-1}]					[t C ha^{-1} yr^{-1}]					
21 Cropland	n.s.	n.s.	4.34	0	0	53.40	240	0.02	0.00	0	0	0	-9.52
31 Permanent Grassland	n.s.	1	7.08	0	0	62.02	240	0	0	0	0	0	-9.52
	n.s.	2	6.00	0	0	67.50	240	0	0	0	0	0	-9.52
	n.s.	3	7.95	0	0	75.18	240	0	0	0	0	0	-9.52
32 Shrub Vegetation	n.s.	1	20.45	0	0	62.02	240	0	0	0	0	0	-5.3
	n.s.	2	20.45	0	0	67.50	240	0	0	0	0	0	-5.3
	n.s.	3	20.45	0	0	75.18	240	0	0	0	0	0	-5.3
33 Vineyards et al.	n.s.	n.s.	3.74	0	0	53.40	240	0	0	0	0	0	-9.52
34 Copse	n.s.	1	20.45	0	0	62.02	240	0	0	0	0	0	-5.3
	n.s.	2	20.45	0	0	67.50	240	0	0	0	0	0	-5.3
	n.s.	3	20.45	0	0	75.18	240	0	0	0	0	0	-5.3
35 Orchards	n.s.	n.s.	24.32	0	0	64.76	240	0	0	0	0	0	-9.52
36 Stony Grassland	n.s.	n.s.	7.16	0	0	26.31	240	0	0	0	0	0	-5.3
37 Unproductive Grassland	n.s.	n.s.	7.01	0	0	68.23	240	0	0	0	0	0	-5.3
41 Surface Waters	n.s.	n.s.	0	0	0	0	240	0	0	0	0	0	0
42 Unproductive Wetland	n.s.	n.s.	6.50	0	0	68.23	240	0	0	0	0	0	-5.3
51 Buildings, Constructions	n.s.	n.s.	0	0	0	0	0	0	0	0	0	0	0
52 Herbaceous Biomass in S.	n.s.	n.s.	9.54	0	0	53.40	240	0	0	0	0	0	-9.52
53 Shrubs in Settlements	n.s.	n.s.	15.43	0	0	53.40	240	0	0	0	0	0	-5.3
54 Trees in Settlements	n.s.	n.s.	20.72	0	0	53.40	240	0	0	0	0	0	-5.3
61 Other Land	n.s.	n.s.	0	0	0	0	0	0	0	0	0	0	0

Legend

altitude zones:
1 < 601 m
2 601 - 1200 m
3 > 1200 m

NFI-regions:
1 Jura
2 Central Plateau
3 Pre-Alps
4 Alps
5 Southern Alps

n.s. = no stratification
annually changing data

6.1.5 Uncertainty Estimates

Table 6-5 gives an overview of uncertainty estimates of activity data (AD) and of emission factors (EF). For categories 4A–4F (highlighted in yellow), the uncertainty of AD mainly depends on the uncertainty of the AREA survey data (see Chapter 6.3.3). For categories 4II–4V and 4G other data sources are relevant; they are presented in detail in the respective chapters (6.X.3) of the LULUCF categories, along with the uncertainty estimates of EF.

In general, AD uncertainty is lower than EF uncertainty, because AD are mostly based on a systematic survey with high spatial resolution (such as AREA or the wildfire database), while EFs include parameters that are difficult to measure or to model such as carbon stocks in biomass, growth rates and biogeochemical processes.

Table 6-5 Uncertainty estimates in the LULUCF sector, expressed as half of the 95% confidence intervals. Highlighted AD uncertainties depend on the uncertainty of the AREA survey.

IPCC category		Gas	Activity data uncertainty	Emission factor uncertainty	Remark
			%	%	
4A1	Forest Land remaining Forest Land	CO_2	2	45	
4A2	Land converted to Forest Land	CO_2	2	45	
4B1	Cropland remaining Cropland	CO_2	5	88	
4B2	Land converted to Cropland	CO_2	6	129	
4C1	Grassland remaining Grassland	CO_2	6	2316	
4C2	Land converted to Grassland	CO_2	6	72	
4D1	Wetlands remaining Wetlands	CO_2	30	100	organic soil
4D2	Land converted to Wetlands	CO_2	5	50	
4E1	Settlements remaining Settlements	CO_2	5	50	
4E2	Land converted to Settlements	CO_2	5	50	
4F2	Land converted to Other Land	CO_2	4	50	
4II	Drained organic soils	N_2O	30	138	
4IID2	Flooded land	CH_4	10	70	
4III	N Mineralization	N_2O	6	135	
4IV2	Indirect emissions Leaching	N_2O	32	162	
4V	Wildfires	CO_2	10	70	
4V	Wildfires	CH_4	10	70	
4V	Wildfires	N_2O	10	70	
4G	Harvested Wood Products	CO_2	3	57	

6.2 Land-use Definitions and Classification Systems

6.2.1 Combination Categories (CC) as derived from AREA Land Use Statistics

The nomenclature of the Swiss Land Use Statistics (AREA) evaluated by the Swiss Federal Statistical Office (SFSO 2006a) is the basis for the land-use categories and subcategories used for land area representation in the LULUCF sector. In the course of the AREA surveys (see Chapter 6.3.1), every hectare of Switzerland's territory was assigned to a land-use category (LU) and to a land-cover category (LC). The 46 land-use categories and 27 land-cover categories of AREA were aggregated to 18 combination categories (CC) as shown in Table 6-6, thus implementing the main categories proposed by IPCC as well as country-specific sub-divisions (see Table 6-2). The first digit of the CC code represents the main land-use category according to IPCC, whereas the second digit stands for respective sub-divisions. All categories of Forest Land, Grassland and Wetlands are reported under managed land in CRF-table 4.1.

The sub-divisions were defined with respect to possible differentiation of biomass densities, carbon turnover, and soil carbon contents. They were defined in 2006 in an evaluation process involving experts from the FOEN, the Swiss Federal Institute for Forest, Snow and

Landscape Research (WSL), the Swiss Federal Statistical Office and Agroscope as well as private consultants. The evaluation process resulted in the elaboration of Table 6-6. CC definition was strongly influenced by the land cover and land use (LC/LU) classification of the Swiss Land Use Statistics AREA (SFSO 2006a). Most criteria and thresholds as defined therein were adopted.

For Forest Land, e.g., the criteria correspond to the NFI thresholds with respect to minimum area, width, crown cover, and tree height.

For LC 31 (land cover shrub), e.g., the criteria include: vegetation height <3 m, degree of coverage >80%, dominated by shrubs, dwarf-shrubs, and bushes.

For LC32 (land cover brush meadows), e.g., the criteria include vegetation height <3 m, degree of coverage 50-80%, dominated by shrubs, dwarf-shrubs, and bushes.

With regard to carbon content in biomass, there is a strong relation to the vegetation type (i.e. land cover in most cases). This is exemplarily reflected by the mainly horizontal arrangement of the individual CCs in Table 6-6. With regard to carbon turnover and soil organic carbon the CC definition was driven by the consideration that most vegetation units are subject to a similar management that leads to comparable C fluxes in biomass and soil.

For individual CCs (especially Forest Land, i.e. CC11, CC12, CC13) further spatial stratifications were introduced (cf. Chapter 6.2.2) with intent to approximate the real/natural differences in carbon stock, carbon turnover and soil conditions as good as possible.

The underlying criteria to include land-use sub-categories such as Shrub vegetation, Vineyards, Low-stem Orchards, Tree Nurseries, Copse and Orchards under Grassland with woody biomass are: (1) They do not fulfil the criteria for forests; (2) There is an agricultural management in general; (3) They all have woody biomass (i.e. perennial vegetation) with grass understory. Under Cropland there are no perennial crops, but only annual crops and leys in arable rotations. All perennial crops are included in the grassland sub-categories.

Table 6-6 Derivation of 18 combination categories (CC) from AREA land-use and land-cover categories.

18 Combination Categories (CC)

Land Cover (NOLC04) acc. to AREA	Settlement and urban areas: Building areas								Transport surfaces					Special urban areas							Recreational areas and cemeteries					
	101 Industrial and commercial areas > 1 ha	102 Industrial and commercial areas < 1 ha	103 Residential areas (one and two-family hous	104 Residential areas (terraced houses)	105 Residential areas (blocks of flats)	106 Public buildings and surroundings	107 Agricultural buildings and surroundings	108 Unspecified buildings and surroundings	121 Motorways	122 Roads	123 Parking areas	124 Railway surface	125 Airports and airfields	141 Energy supply plants	142 Waste treatment plants	143 Other supply or waste treatment plants	144 Dumps	145 Quarries, mines	146 Construction sites	147 Unexploited urban areas	161 Public parks	162 Sport facilities	163 Golf courses	164 Camping areas	165 Garden allotments	166 Cemeteries
10 Artificial areas																										
11 Sealed surfaces	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51
12 Buildings	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51
13 Greenhouses	52	52	52	52	52	52	52	52			52	52	52						52	52	52	52	52	52	52	52
14 Gardens with border and patch structures	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52			52	52	52	52	52	52	52	52
15 Lawns	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52			52	52	52	52	52	52	52	52
16 Trees in artificial areas	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54			54	54	54	54	54	54	54	54
17 Mix of small structures	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52			52	52	52	52	52	52	52	52
20 Grass and herb vegetation																										
21 Grass and herb vegetation	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52
30 Brush vegetation																										
31 Shrub	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53
32 Brush meadows	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53
33 Short-stem fruit trees	53	53	53	53	53	53	53	53	53	53	53	53								53	53				53	53
34 Vines	53	53	53	53	53	53	53	53	53	53	53	53								53	53				53	53
35 Permanent garden plants and brush crops	52	52	52	52	52	52	52	52	52	52	52	52								52	52				52	52
40 Tree vegetation																										
41 Closed forest	54	54	54	54	54	54	54	54	54		54									54	54	54		54	54	54
42 Forest edges	54	54	54	54	54	54	54	54	54		54			54	54	54				54	54	54	54	54	54	54
43 Forest strips	54	54	54	54	54	54	54	54	54		54			54	54	54				54	54	54		54	54	54
44 Open forest	54	54	54	54	54	54	54	54	54		54			54	54	54				54	54	54		54	54	54
45 Brush forest																					53			53		
46 Linear woods	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54
47 Clusters of trees	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54
50 Bare land																										
51 Solid rock	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51
52 Granular soil	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51
53 Rocky areas	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52
60 Watery areas																										
61 Water	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41
62 Glacier, perpetual snow																										
63 Wetlands	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42
64 Reedy marshes	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42

Land Cover (NOLC04) acc. to AREA	Agricultural areas: Orchards, vineyards, horticulture			Arable and grassland			Alpine grazing areas			Forest areas: Forest (not used for agriculture)				Unproductive areas: Lakes and rivers			Unproductive land			
	201 Orchards	202 Vineyards	203 Horticulture	221 Arable land, in general	222 Semi-natural grassland, in general	223 Farm pastures, in general	241 Alpine meadows, in general	242 Alpine pastures, in general	243 Alpine sheep grazing pastures, in general	301 Forest	302 Afforestation	303 Lumbering areas	304 Damaged forest	401 Lakes	402 Streams, rivers	403 Flood protection structures	421 Unused	422 Avalanche and rockfall protection structures	423 Alpine sports facilities	424 Landscape intervention
10 Artificial areas																				
11 Sealed surfaces		51	51											51	51	51		51	51	51
12 Buildings																				
13 Greenhouses			21																	
14 Gardens with border and patch structures		21	21	21	21		21			12										
15 Lawns		31	31																	
16 Trees in artificial areas																				
17 Mix of small structures		21	21																	
20 Grass and herb vegetation																				
21 Grass and herb vegetation	31	31	31	21	31	31	31	31	31		11	12	12	37	37	37	37	37	37	31
30 Brush vegetation																				
31 Shrub		32	32								11	12	12	32	32	32	32	32	32	32
32 Brush meadows		32	32		32	32	32	32			11	12	12	32	32	32	32	32	32	32
33 Short-stem fruit trees	33		33																	
34 Vines		33	33																	
35 Permanent garden plants and brush crops			33							12										
40 Tree vegetation																				
41 Closed forest	35									12	11					12		12		
42 Forest edges	35									12	11	12	12			12		12		
43 Forest strips	35									12	11					12		12		
44 Open forest	35				12	12	12	12	13	12	11	12	12			12		12	12	12
45 Brush forest										13						13		13		
46 Linear woods	34	34	34	34	34	34	34	34	34		11	12	12	34	34	34	34	34	34	34
47 Clusters of trees	34	34	34	34	34	34	34	13	34		11	12	12	34	34	34	34	34	34	34
50 Bare land																				
51 Solid rock												13	13	61	61	61	61	61	61	61
52 Granular soil		61	61									12	12	61	61	61	61	61	61	61
53 Rocky areas		36	36			36	36	36			11	13	13	36	36	36	36	36	36	36
60 Watery areas																				
61 Water														41	41	41				41
62 Glacier, perpetual snow																	61			
63 Wetlands					42	42	42	42	42			12	13	42	42	42	42	42	42	42
64 Reedy marshes				21	42	42	42	42	42					42	42	42	42			

Combination Categories (CC):

11 Afforestations
12 Productive forest
13 Unproductive forest
21 Cropland
31 Permanent grassland
32 Shrub vegetation
33 Vineyards, Low-stem Orchards, Tree nurseries
34 Copse
35 Orchards
36 Stony grassland
37 Unproductive grassland
41 Surface waters
42 Unproductive wetland
51 Buildings and construction
52 Herbaceous biomass in settlements
53 Shrubs in settlements
54 Trees in settlements
61 Other land

6.2.2 Spatial Stratification

In order to quantify carbon stocks and GHG emissions by sources and removals by sinks in the LULUCF sector as accurately as possible, Switzerland's territory was stratified by means of three site criteria: soil type (mineral or organic), altitude and forest production region.

Most soils in Switzerland are mineral soil types. For mapping the occurrence of organic soils, two datasets were used: (i) the digital soil map "BEK" (SFSO 2000a) and (ii) the Inventory of Raised Bogs of National Importance (Appendix to Swiss Confederation 1991a).

Two units of the digital soil map contain mainly organic soils (Figure 6-3): The codes F1 and Q3, representing Histosols in the Central Plateau and in Alpine valleys, respectively, are good indicators for organic soils in the lowlands. As the soil map has no appropriate unit for organic soils in mountainous areas the maps of the Inventory of Raised Bogs (with a scale of 1:25'000) were used in addition. All areas covered by this inventory were assumed to have organic soils (see Figure 6-3).

For Forest Land and – in part – Grassland, three altitudinal belts were differentiated: <601 m a.s.l. (meters above sea level), 601-1200 m a.s.l., and >1200 m a.s.l. (Figure 6-3). Altitude data are available on a hectare-grid from the Swiss Federal Statistical Office (SFSO 1997).

Forest Land was furthermore differentiated into the five production regions of the National Forest Inventory NFI (EAFV/BFL 1988; Brassel and Brändli 1999; Brändli 2010). The NFI regions were adopted from EAFV/BFL (1988) as shown in Figure 6-3:

1. Jura
2. Central Plateau
3. Pre-Alps
4. Alps
5. Southern Alps.

Applying all spatial stratifications, 30 different strata (referred to as subscript i in Chapter 6.1.3.2) would be theoretically possible. Not all of them, but altogether 28 have been actually realised and applied for the calculation of LULUCF-associated carbon emissions and removals.

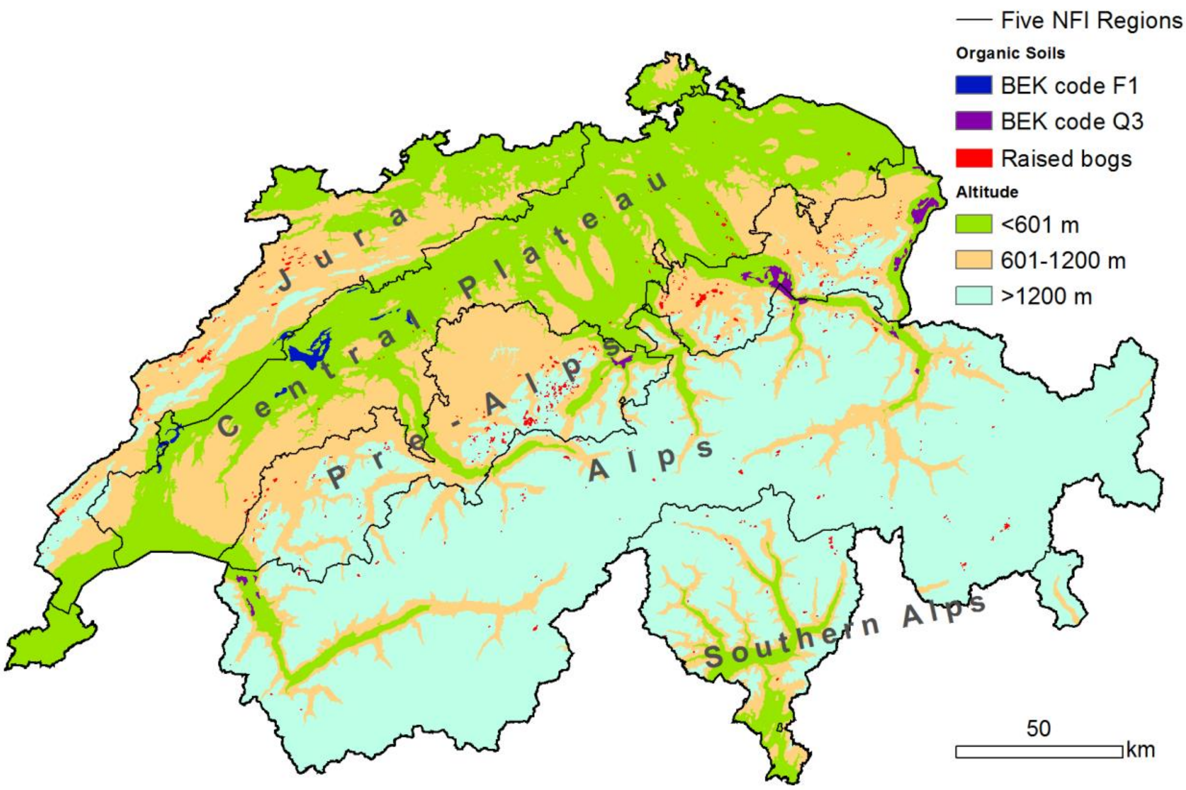


Figure 6-3 Map showing the spatial stratification according to NFI region, altitude, and soil type.

6.2.3 The Land-use Tables and Change Matrices

In Table 6-7 the land-use statistics resulting from spatial stratification (Chapter 6.2.2) and interpolation in time (Chapter 6.3.2) are exemplarily shown for the year 1990. The table gives also an overview of the size of the individual spatial strata.

Table 6-7 Land use (in terms of combination categories CC) projection by the end of 1990, stratified separately for altitude (3 zones), soil type (mineral or organic) and NFI region (1-5), in kha.

CC:	11	12	13	21	31	32	33	34	35	36	37	41	42	51	52	53	54	61	Sum
Altitude																			
<601	1.1	222.7	0.5	299.5	152.0	2.6	22.7	37.8	1.2	0.5	2.9	137.5	5.2	116.2	47.4	2.8	18.6	1.9	1072.6
601-1200	1.5	501.4	8.0	132.3	360.0	8.6	3.8	40.1	0.4	2.4	1.5	10.0	5.6	47.0	17.1	1.0	5.4	7.7	1153.8
>1200	1.4	382.8	77.1	0.4	425.4	144.5	0.0	30.0	0.0	148.8	61.9	13.5	14.4	11.4	3.7	0.2	1.0	585.6	1902.0
	4.0	1106.8	85.6	432.2	937.4	155.7	26.5	107.8	1.6	151.6	66.3	160.9	25.1	174.5	68.2	3.9	24.9	595.2	4128.4
Soil																			
mineral	4.0	1103.5	85.6	420.4	931.8	155.6	26.4	107.3	1.6	151.6	66.0	160.4	21.9	172.7	67.5	3.9	24.8	595.2	4100.1
organic	0.0	3.3	0.1	11.8	5.6	0.1	0.1	0.5	0.0	0.0	0.3	0.5	3.2	1.8	0.7	0.1	0.1	0.027	28.3
	4.0	1106.8	85.6	432.2	937.4	155.7	26.5	107.8	1.6	151.6	66.3	160.9	25.1	174.5	68.2	3.9	24.9	595.2	4128.4
NFI-region																			
1	0.7	197.2	5.3	78.0	122.6	0.9	4.7	14.8	0.3	0.2	0.6	23.6	1.2	26.8	10.9	0.5	4.7	0.5	493.5
2	0.8	227.1	0.4	306.9	152.4	0.9	9.9	31.1	1.0	0.2	1.6	70.3	4.1	84.9	34.7	1.6	12.6	0.7	941.2
3	1.0	214.3	9.2	30.4	261.3	10.4	0.8	21.7	0.1	8.5	6.8	30.2	12.0	26.8	9.2	0.5	2.9	15.0	661.0
4	1.2	331.6	49.5	13.8	365.4	110.2	9.5	31.0	0.2	118.0	49.2	26.2	7.2	26.9	9.8	0.8	3.0	524.7	1678.1
5	0.3	136.6	21.2	3.0	35.7	33.3	1.5	9.2	0.0	24.6	8.1	10.7	0.7	9.2	3.7	0.6	1.9	54.2	354.6
	4.0	1106.8	85.6	432.2	937.4	155.7	26.5	107.8	1.6	151.6	66.3	160.9	25.1	174.5	68.2	3.9	24.9	595.2	4128.4

Table 6-8 shows the overall trends of land-use changes between 1990 and 2013. For example, the area of afforestations (CC11) decreased by 76% during this period, while the area of unproductive forests (CC13) increased by 7%. CC11 is decreasing because the area of new afforestations has been decreasing during this period and because most of the afforestations turn to productive forests after a certain time period.

Table 6-8 Statistics of land use (in terms of combination categories CC) and relative change (%) between 1990 and 2013, in kha.

CC:	11	12	13	21	31	32	33	34	35	36	37	41	42	51	52	53	54	61	Sum
Year:																			
1990	4.0	1106.8	85.6	432.2	937.4	155.7	26.5	107.8	1.6	151.6	66.3	160.9	25.1	174.5	68.2	3.9	24.9	595.2	4128.4
1991	3.9	1109.0	86.0	431.4	935.5	155.2	26.5	106.6	1.5	151.4	66.1	160.9	25.1	176.2	68.7	4.0	25.3	594.9	4128.4
1992	3.8	1111.2	86.4	430.6	933.7	154.7	26.6	105.4	1.4	151.1	66.0	160.9	25.1	177.9	69.3	4.0	25.6	594.5	4128.4
1993	3.7	1113.3	86.8	429.8	932.1	154.2	26.5	104.2	1.4	150.9	65.8	160.9	25.1	179.5	69.8	4.1	25.9	594.2	4128.4
1994	3.5	1115.3	87.1	428.6	931.1	153.6	26.5	103.1	1.3	150.7	65.7	161.0	25.1	181.1	70.4	4.1	26.1	594.0	4128.4
1995	3.3	1117.1	87.5	427.0	930.7	153.0	26.5	102.0	1.3	150.5	65.6	161.0	25.2	182.7	71.1	4.2	26.1	593.7	4128.4
1996	3.1	1118.6	87.8	425.4	930.5	152.5	26.4	101.0	1.3	150.4	65.5	161.0	25.2	184.2	71.8	4.2	26.1	593.4	4128.4
1997	2.9	1120.1	88.1	423.7	930.5	152.0	26.3	99.9	1.3	150.3	65.4	161.0	25.2	185.7	72.6	4.2	25.9	593.1	4128.4
1998	2.7	1121.4	88.4	421.9	930.5	151.8	26.2	98.9	1.2	150.2	65.3	161.1	25.2	187.3	73.4	4.2	25.8	592.9	4128.4
1999	2.5	1122.7	88.6	420.2	930.5	151.5	26.1	97.8	1.2	150.3	65.2	161.1	25.2	188.8	74.3	4.2	25.6	592.6	4128.4
2000	2.2	1123.9	88.9	418.5	930.4	151.3	26.1	96.7	1.2	150.3	65.1	161.1	25.2	190.3	75.1	4.2	25.5	592.4	4128.4
2001	2.0	1125.2	89.2	416.8	930.4	151.0	26.0	95.6	1.1	150.3	65.0	161.2	25.2	191.9	75.9	4.2	25.3	592.2	4128.4
2002	1.8	1126.5	89.4	415.0	930.4	150.8	25.9	94.6	1.1	150.3	64.9	161.2	25.3	193.4	76.7	4.2	25.2	591.9	4128.4
2003	1.6	1127.8	89.7	413.3	930.3	150.6	25.8	93.5	1.1	150.3	64.8	161.2	25.3	194.9	77.5	4.2	25.0	591.7	4128.4
2004	1.3	1129.1	89.9	411.6	930.3	150.3	25.7	92.4	1.0	150.3	64.6	161.3	25.3	196.5	78.3	4.2	24.8	591.4	4128.4
2005	1.2	1131.1	90.2	411.1	930.4	149.9	25.5	90.7	1.0	150.2	64.4	161.3	25.3	197.9	78.8	4.1	24.3	591.0	4128.4
2006	1.1	1133.1	90.5	411.0	930.5	149.6	25.2	88.9	1.0	150.2	64.2	161.4	25.3	199.1	79.1	4.0	23.8	590.5	4128.4
2007	1.1	1135.0	90.6	411.2	930.5	149.3	25.0	87.1	0.9	150.1	63.9	161.5	25.2	200.1	79.4	3.9	23.3	590.0	4128.4
2008	1.0	1137.2	90.9	411.4	930.9	148.7	24.8	85.6	0.9	150.1	63.7	161.6	25.2	200.8	79.5	3.8	22.9	589.3	4128.4
2009	1.0	1138.8	91.2	409.9	930.9	148.3	24.7	84.5	0.9	150.1	63.5	161.7	25.2	202.2	80.2	3.9	22.7	588.9	4128.4
2010	1.0	1139.8	91.4	408.4	930.6	148.1	24.6	83.6	0.9	150.1	63.4	161.7	25.2	203.7	80.9	3.9	22.6	588.7	4128.4
2011	1.0	1140.7	91.6	406.8	930.3	147.9	24.5	82.8	0.8	150.1	63.3	161.7	25.3	205.1	81.5	3.9	22.5	588.4	4128.4
2012	1.0	1141.7	91.8	405.2	930.0	147.7	24.4	82.0	0.8	150.1	63.2	161.8	25.3	206.6	82.2	3.9	22.4	588.2	4128.4
2013	0.9	1142.7	92.0	403.7	929.8	147.5	24.3	81.2	0.8	150.1	63.1	161.8	25.3	208.1	82.9	3.9	22.3	588.0	4128.4
Change:	-76	3	7	-7	-1	-5	-8	-25	-49	-1	-5	1	1	19	22	-1	-10	-1	0

The annual rates of change in the entire territory of Switzerland (change-matrices, see examples for 1990 and 2013 in Table 6-9) are achieved by adding up the annual change rates of all hectares per combination category (CC). For calculating the carbon stock changes, fully stratified (up to 28 strata, cf. Chapter 6.2.2) land-use change tables are used for each year (Meteotest 2015). More aggregated change-matrices are reported in CRF-table 4.1 for each year 1990-2013.

It is worth noting that in general the numbers given in the change-matrices (Table 6-9) cannot be directly compared with the numbers in the CRF-tables 4A2–4F2, where the cumulative area remaining in the respective category in the reporting year is recorded (cf. the description of conversion time of 20 years in Chapter 6.1.3.3). In contrast, the change matrices present the land-use changes occurring in the specified year only.

Table 6-9 Annual rates of land-use change in 1990 and in 2013 (change matrices). Units: ha/year, rounded values. Empty cells indicate that no change has occurred.

1990	change to CC																		
change from CC	11	12	13	21	31	32	33	34	35	36	37	41	42	51	52	53	54	61	decrease
11		369	1	0	0	0		0						0	0	0		0	372
12			135	5	125	86	6	82		12	19	11	7	117	27	11	17	49	709
13		534			128	37	0	45		3	2	1	1	5	0	0	1	9	767
21	8	1			663	6	181	40	1	4	4	4	4	632	317	21	18	22	1926
31	136	166	231	718		1007	123	560	4	46	43	9	11	870	490	27	44	68	4554
32	24	1022	687	2	126		9	337		14	14	6	0	24	8	5	3	30	2312
33	1	2		126	65	4		33	2	0	1	0		50	26	4	3	5	323
34	30	680	33	151	1091	60	40		11	10	24	4	4	207	114	8	54	15	2537
35		0		8	13	0	4	47						4	2	0	0	0	80
36	3	27	25	2	162	243	1	41			89	4	0	8	1	0		45	652
37	7	26	6	1	8	234	1	68		10		3	0	6	1		0	13	384
41	0	4	1	2	2	6	0	4		4	1		17	11	2	1	0	99	156
42	5	27	5	1	3	2	0	3		0	0	6		4	1	0	0	1	59
51	38	18	1	86	158	11	5	11		3	5	6	4		271	58	46	5	726
52	7	4		16	32	3	1	2		0	1	1	2	349		68	387	0	874
53	5	9	0	6	7	2	0	2				0	2	45	28		46	0	150
54	2	6		1	2	0	0	3			0	0	1	78	152	8		0	253
61	4	41	16	16	67	93	8	32		287	33	96	2	13	1	0	1		709
increase	271	2936	1141	1140	2652	1794	381	1310	18	394	236	152	55	2425	1443	211	621	362	17543

2013	change to CC																		
change from CC	11	12	13	21	31	32	33	34	35	36	37	41	42	51	52	53	54	61	decrease
11		71	0			0								0					72
12			224	1	178	140	2	107		31	21	15	12	90	26	12	9	73	943
13		515			158	58		27		4	2	1	1	3	0	0	0	10	779
21	2	0			1287	5	140	17	0	4	11	8	9	496	286	13	5	12	2294
31	17	77	176	444		725	73	319	2	71	30	7	9	756	403	14	9	81	3215
32	3	646	510	2	127		3	288		18	11	5	0	13	4	2	1	32	1664
33	0	1		135	95	5		20	1	1	0		0	35	23	1	2	6	326
34	3	523	31	53	770	67	15		4	10	23	6	1	126	70	3	22	18	1745
35				1	6		2	16						1	0				26
36	0	17	20	3	80	195	1	44			51	4		3	0			40	460
37	2	14	3	1	2	181		47		13		3	0	4	1			12	283
41	0	2	0	0	1	5		2		3	3		9	6	1	0		100	133
42	0	18	4		0	0		1		1		7		2	0			1	36
51	17	9	0	63	144	8	3	6		6	6	6	2		287	51	21	5	635
52	6	3	0	16	41	3	1	3		1	2	1	2	411		51	216	0	757
53	2	10		3	11	2	0	1		0	1	0	0	49	39		38	0	156
54	1	3		0	2	0		2			0		0	96	302	18			425
61	1	28	11	16	46	73	4	28		285	16	101	1	6	1	0			618
increase	55	1938	981	740	2947	1467	244	928	6	449	177	164	49	2098	1445	165	323	391	14568

6.3 Approaches Used for Representing Land Areas and Land-use Databases

6.3.1 Swiss Land Use Statistics (AREA)

Data of the Swiss Land Use Statistics (AREA) evaluated by the Swiss Federal Statistical Office (SFSO 2013) are the basis of activity data. In the course of the AREA surveys, every hectare of Switzerland's territory (4'128 kha) was assigned to one of 46 land-use categories and to one of 27 land-cover categories by means of stereographic interpretation of aerial photos (SFSO 2006a). The AREA surveys were launched in 2004 and completed in 2013.

For the reconstruction of the land use conditions in Switzerland during the period 1990-2013 three datasets are used:

- Land Use Statistics “1979/85” (AREA1)

- Land Use Statistics “1992/97” (AREA2)
- Land Use Statistics “2004/09” (AREA3)

The aerial photos for AREA1, AREA2 and AREA3 were taken 1977-1986, 1990-1998 and 2004-2009, respectively. They were simultaneously evaluated according to the newly designed AREA set of land-use and land-cover categories based on the nomenclature 'NOAS04' (SFSO 2006a).

The inter-survey period is not identical throughout the Swiss territory, but varies regionally. It averages approximately 12 years. This methodical characteristic needs to be considered when reconstructing the annual country-wide status of land use or when calculating annual rates of land-use change.

6.3.2 Interpolation of the Status for each Year

The exact dates of aerial photo shootings are known for each hectare. However, the exact occurrence date (year) of a land-use change on a specific hectare is unknown. The actual change can have taken place in any year between two AREA surveys. In this study, it is assumed that the probability of a land-use change from AREA1 to AREA2 and from AREA2 to AREA3 is uniformly distributed over the respective interim period between two surveys. Therefore, the land-use change of each hectare has to be equally distributed over its specific interim period.

Thus, the land-use status for the years between two data collection dates can be calculated by linear interpolation. Dates of aerial photo shootings (i.e. starting and ending year of the inter-survey period) and the land-use categories of AREA1, AREA2 and AREA3 for every hectare are used for these calculations. An example is shown in Figure 6-4: A hectare has been assigned to the land-use category Cropland in AREA1 (aerial photo in 1980). A land-use change to Surrounding of Buildings has been discovered 10 years later (1990) in AREA2.

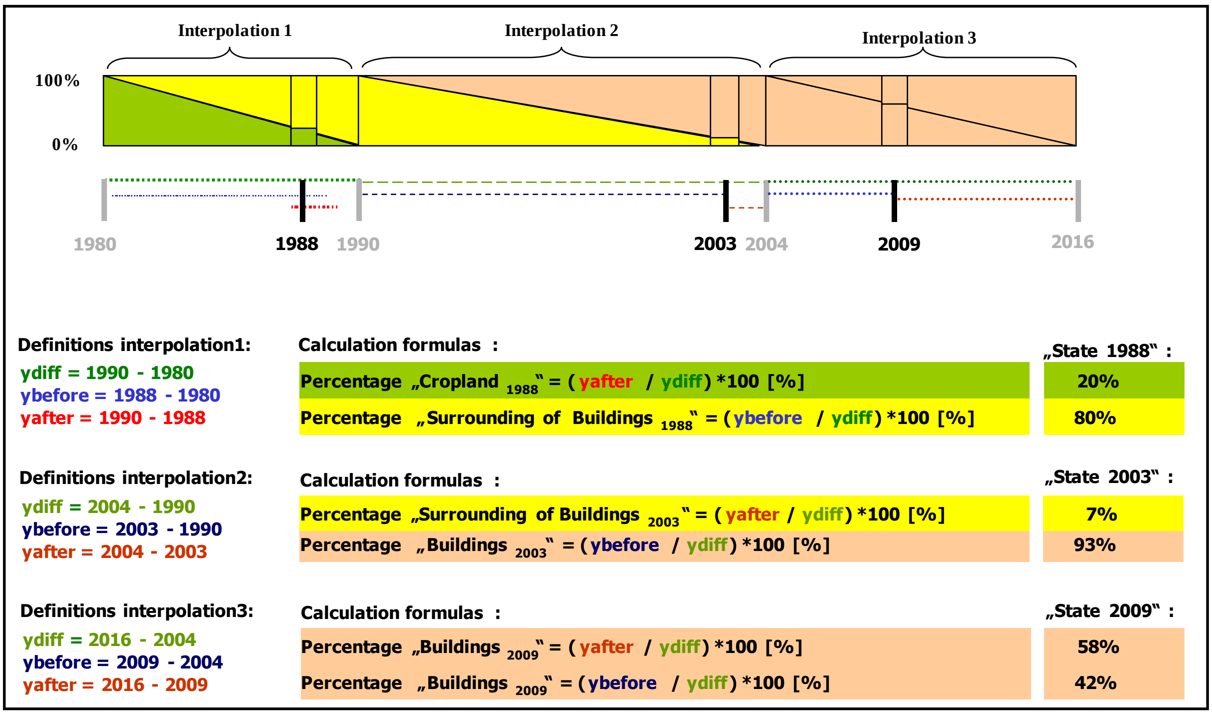


Figure 6-4 Hypothetical linear development of land-use changes between AREA1, AREA2 and AREA3 considering as example a hectare changing from “Cropland” to “Surrounding of Buildings” and then from "Surrounding of Buildings" to "Buildings". For 2009, a linear interpolation has been carried out between AREA3 and a virtual fourth survey modelled for the year 2016 (here resulting in no change of land use).

The “state 1988” of that hectare is determined by calculating the fractions of the two land-use categories for the year 1988. A linear development from “Cropland” to “Surrounding of Buildings” during the whole interim period is assumed. Thus, in 1988 the hectare is split up in two fractions: 80% is “Surrounding of Buildings” and 20% is “Cropland”. The same procedure can be applied for two survey dates between AREA2 and AREA3 (here exemplarily shown for the period 1990-2004, highlighting “state 2003”).

AREA3 comprehends aerial photos from six years (2004-2009). Therefore, the land-use changes occurring after AREA3 are calculated from the linear development detected between AREA3 and a virtual fourth survey, AREA4 (see Figure 6-4: example “state 2009”). AREA4 was modeled for each sample plot using a Markov-chain approach, where transition probabilities between AREA3 and AREA4 were assessed based on transition distribution between AREA2 and AREA3 within each spatial stratum (Sigmaplan 2014). This approach was evaluated successfully by modeling a virtual AREA3 from transition probabilities between AREA1 and AREA2 and comparing the results to the actual interpretation of AREA3.

The status for each individual year in the period 1990-2013 for the whole Swiss territory results from the summation of the fractions of all hectares per combination category CC, additionally considering the spatial strata where appropriate.

6.3.3 Uncertainties and Time-series Consistency of Activity Data

An overview of uncertainty estimates for activity data (AD) and emission factors (or biomass parameters) is shown in Table 6-5. Details related to uncertainties of AREA data are presented in this chapter, while uncertainties of other AD and emission factors are presented in the respective chapters (6.X.3) of the LULUCF categories.

In most cases (as highlighted in yellow in Table 6-10), the uncertainty of AD for categories 4A–4F depends on the quality of the AREA survey data. The uncertainty of AREA-based activity data has two main sources (Table 6-10). They have been quantified on the basis of the AREA data (SFSO 2013) as follows:

1) Interpretation error: In the AREA survey, the interpretation of the aerial photos is checked by a second independent interpreter. The portion of sampling points with a mismatch of the first and the second interpretation is used as the uncertainty of the interpretation. This uncertainty of interpretation integrates all errors related to the manual interpretation of land-use and land-cover classes on aerial photographs. While it is clear that this is rather an estimate of the maximum potential interpretation error than of the actual interpretation error, it is reported hereafter unless more accurate information is available.

2) Statistical sampling error: In the AREA survey, the land-use types are interpreted on points situated on a regular 100x100 m grid. Thus, the uncertainty of the surface area covered by a certain land-use type or land-use change decreases with increasing numbers of sampling points. Assuming a binomial distribution of the errors, this uncertainty is calculated as

$$\text{Usampling} = 100 * 1.96 * (\text{number of points})^{-0.5}$$

The number of sampling points lies between 2'472 (for 4D2) and 1'374'367 (for 4C1) leading to values of Usampling between 3.9% and 0.2%.

The overall uncertainty was calculated as:

$$\text{Uoverall} = (\text{Uinterpret}^2 + \text{Usampling}^2)^{0.5}$$

Finally, conservatively rounded values of the calculated overall uncertainties were chosen for further processing in the uncertainty analysis.

In category 4D1 (Wetland remaining wetland) CO_2 emissions are dominated by net carbon stock losses in organic soils. The uncertainty of the area of organic soils is around 30% according to Leifeld et al. (2003: 61).

Consistency: Time series for activity data are all considered consistent; they are calculated based on consistent methods for interpolation and extrapolation and homogenous databases.

Table 6-10 Sources of AD uncertainty and overall uncertainties in the area calculations, expressed as half of the 95% confidence intervals. Highlighted AD uncertainties depend on the quality of the AREA survey data. Exception for category 4D1 is mentioned in the main text. Calculations are based on AREA data from SFSO (2013).

Category	Description	Interpretation uncertainty	Sampling uncertainty	Overall uncertainty, calculated value	Overall uncertainty, rounded value (%)
4A1	Forest Land remaining Forest Land	1.1	0.2	1.09	2
4A2	Land converted to Forest Land	1.1	1.2	1.60	2
4B1	Cropland remaining Cropland	4.9	0.3	4.89	5
4B2	Land converted to Cropland	4.9	2.1	5.31	6
4C1	Grassland remaining Grassland	5.2	0.2	5.23	6
4C2	Land converted to Grassland	5.2	1.0	5.33	6
4D1	Wetlands remaining Wetlands	0.9	0.5	1.02	2
4D2	Land converted to Wetlands	0.9	3.9	4.05	5
4E1	Settlements remaining Settlements	4.4	0.4	4.41	5
4E2	Land converted to Settlements	4.4	1.1	4.54	5
4F1	Other Land remaining Other Land	1.4	0.3	1.40	NA
4F2	Land converted to Other Land	1.4	2.8	3.16	4

6.3.4 QA/QC and Verification of Activity Data

The general QA/QC measures are described in Chapter 1.2.3.

The AREA survey is a well-defined and controlled, long-term process in the responsibility of the Swiss Federal Statistical Office (SFSO 2006a). The data supplied by SFSO (2013) have been checked for suitability and consistency (Sigmaplan 2014).

The temporal interpolation and extrapolation of the AREA sample is quite a complex procedure, whose internal consistency is checked systematically as described in Sigmaplan (2014). Further checks (interannual comparisons, plausibility) are carried out after producing the land-use change tables presented in Chapter 6.2.3.

A systematic cross-check between the activity data reported under LULUCF category 4A and under the KP activity Forest management is carried out (see Chapter 11.2.3).

It was assured that the total country area remained constant over the inventory period.

6.3.5 Recalculations of Activity Data

There were no recalculations related to land area data.

6.3.6 Planned Improvements for Activity Data

It is planned to integrate most recent land-use data from the fourth AREA survey that has recently been launched at the Swiss Federal Statistical Office in the next submission.

It is also planned to implement a more complete and consistent dataset defining the geographical distribution of organic soils in Switzerland that has recently been compiled (Wüst et al. 2015).

6.4 Category 4A – Forest Land

6.4.1 Description

Approach 1 Key category 4A1
CO_2 from Forest Land remaining Forest Land (level)
Approach 1 Key category 4A2
CO_2 from Land converted to Forest Land (level and trend)
Approach 2 Key category 4A1
CO_2 from Forest Land remaining Forest Land (level)
Approach 2 Key category 4A2
CO_2 from Land converted to Forest Land (level and trend)

Only temperate forests are occurring in Switzerland. Forest is defined as a minimum area of land of 0.0625 ha with crown cover of at least 20% and a minimum width of 25 m. The minimum height of the dominant trees must be 3 m or have the potential to reach 3 m at maturity in situ (FOEN 2006h). The following forest areas are not subject of the criteria of minimum stand height and minimum crown cover, but must have the potential to achieve it: afforested, regenerated, as well as burned, cut or damaged areas. Although orchards, parks, camping grounds, open tree formations in settlements, gardens, cemeteries, sports and parking fields may fulfil the (quantitative) forest definition, they are not considered as forests (FOEN 2006h).

For reporting in the CRF-tables, the different forest types are allocated to afforestations (CC11), productive forest (CC12) and unproductive forest (CC13) based on AREA categories (see Table 6-2 and Table 6-6; SFSO 2006a). A detailed description of the category unproductive forest CC13 can be found in Chapter 6.4.2.9.

6.4.2 Methodological Issues

6.4.2.1 Choice of Method and National Forest Inventories

The calculation approach and the applied conversion time periods for different land-use changes within, from and to forest land and the respective carbon pools are shown in Table 6-3.

Data for growing stock, gross growth (gain in carbon stock of living biomass), cut and mortality (losses in carbon stock of living biomass) were derived from the four available

Swiss National Forest Inventories (NFI, see Table 6-11). A description of NFI 1 and NFI 2 methodologies can be found in EAFV/BFL (1988) and in Brassel and Brändli (1999). Data and methodology of NFI 3 are described in Brändli (2010). The inventories NFI 1, 2 and 3 are based on full surveys that were repeated in intervals of approximately 10 years. The fourth inventory (NFI 4, 2009-2017) is carried out as a continuous survey where a rotating subsample of approximately 12% of the Swiss forests is surveyed and evaluated every year. Otherwise, the methodology remained identical to Brändli (2010).

For assembling the results for the GHG inventory 1990-2013, NFI 4 data for the years 2009-2013 were available. Results of this 5-year subset of the NFI 4 are summarised in the data release NFI 4b (Abegg et al. 2014; Rigling and Schaffer 2015).

Table 6-11 Characteristics of the National Forest Inventories 1, 2, 3 and 4b, accessible forest sample plots without brush forest.

	NFI 1	NFI 2	NFI 3	NFI 4b
Inventory cycle	1983-1985	1993-1995	2004-2006	2009-2013
Grid size	1 x 1 km	1.4 x 1.4 km	1.4 x 1.4 km	1.4 x 1.4 km
Terrestrial sample plots	10'981	6'412	6'608	3'376
Measured single trees	128'441	76'394	77'959	40'290

6.4.2.2 Three-year Averaging of Forest Carbon Pools

The Revised 1996 IPCC Guidelines (IPCC 1997a) recommend working with three-year averages to report carbon changes in “Forest and Other Woody Biomass Stocks”. Further, the 2003 IPCC GPG (IPCC 2003) describes how to deal with interannual variability and states that “it is good practice to consistently report emissions using longer-term averages of environmental conditions or actual annual estimates of emissions when estimating stock changes”.

Changes in the carbon pools reported for the Swiss forest sector reflect annual fluctuations in management, weather conditions and natural disturbances. Therefore, three-year moving averages are calculated for all changes in forest carbon pools in order to smooth out high interannual fluctuations.

Three-year moving averages for the inventory year X are calculated as the average of the years X, X-1 and X-2. For example, the value for the inventory year 2004 is the average value of the years 2002-2004. This “backward-averaging” was used instead of calculating the mean over the current, the preceding and the succeeding years (mean of the years X-1, X, X+1), because

- if X is the most recent inventory year, X+1 data generally are not available in time (for submission in year X+2);
- growth (gain) of living biomass, cut and mortality (loss) and the amount of dead wood is more influenced by the previous years than by the following year.

This “backward-averaging” introduces a certain time-lag in the calculated values and can complicate the interpretation of the resulting CO_2 emissions and removals.

6.4.2.3 Stratification

Spatial Strata

Forests in Switzerland reveal a high heterogeneity in terms of altitude, growth conditions, tree species composition, and inter-annual growth variability. To account for the heterogeneity, the Swiss NFI uses a spatial stratification based on five production regions and three elevation belts (Brändli 2010). To find explanatory variables that significantly reduce the variance of gross growth, an analysis of variance was done (Table 6-12).

Table 6-12 Analysis of variance of gross growth of data from NFI 2 and NFI 3. Explanatory variables: Tree species, NFI production region, and elevation.

	Gross growth	
	F-value	**p-value**
Coniferous / Deciduous	421	<0.0001
Production region	45	<0.0001
Elevation	34	<0.0001

The analysis of variance indicated that production region, elevation, and tree species all significantly explain differences in gross growth. Therefore, the explanatory variables considered here are:

- tree species (coniferous and deciduous species).
- the five NFI production regions: 1. Jura, 2. Central Plateau, 3. Pre-Alps, 4. Alps, 5. Southern Alps
- elevation (<601 m, 601-1200 m, >1200 m)

Values for growing stock, gross growth, harvesting and mortality were calculated and applied for each of these 30 strata.

Since only the data for the years 2009 to 2013 of the continuously sampled NFI 4 (see Chapter 6.4.2.1) are available, several spatial strata were represented by a low number of plots (Thürig et al. 2015). Due to the large variability between sample plots, a minimum number of sample plots is needed to obtain reliable estimates of means and sampling errors. Smaller strata were thus merged with neighboring strata for this submission. For NFI 4b, the following strata were aggregated and treated as single strata:

- Plateau 601-1200 m and >1200 m: new stratum Plateau > 600 m (283 plots)
- Pre-Alps ≤600 m and 601-1200 m: new stratum Pre-Alps ≤ 1200 m (385 plots)
- Alps West ≤600 m and 601-1200 m: new stratum Alps West ≤1200 m (148 plots)
- Alps East ≤600 m and 601-1200 m: new stratum Alps East ≤1200 m (171 plots)

Separating Mixed Forests into Coniferous and Deciduous Sites

In Switzerland, most forests are mixed stands. However, the forest area derived by the Swiss land use statistics does not allow separating coniferous and deciduous sites.

To derive species specific measures for growing stock, gross growth (gain of living biomass), cut and mortality (loss of living biomass), the total forest area has to be divided according to the species mixture. The emission factor per stratum is then calculated as the weighted mean of both species. The required ratio of coniferous forest area (Rc) per spatial stratum was calculated by dividing the sum of the biomass of the conifers (Bc) over the sum of the biomass of all trees (B). The ratios for each spatial stratum are displayed in Table 6-13.

Rci = Bci / Bi i = spatial strata

As both species add up to 1 (or 100%) the rate of deciduous forest area (Rd) is:

Rdi = 1 - Rci i = spatial strata

Table 6-13 Ratio of coniferous and deciduous species for 1985-1994 (derived from NFI 1 and NFI 2; source: Brassel and Brändli 1999), for 1995-2005 (derived from NFI 2 and NFI 3 data; source: Brändli 2010) and for 2006-2013 (derived from NFI 3 and NFI 4b data; source: Abegg et al. 2014). Some NFI 4b strata are aggregated as described above (Thürig et al. 2015).

		1985 - 1994		**1995 – 2005**		**2006-2013**	
NFI region	**Altitude [m]**	**Coniferous**	**Deciduous**	**Coniferous**	**Deciduous**	**Coniferous**	**Deciduous**
1	<601	0.31	0.69	0.31	0.69	0.31	0.69
	601-1200	0.54	0.46	0.52	0.48	0.50	0.50
	>1200	0.74	0.26	0.72	0.28	0.76	0.24
2	<601	0.56	0.47	0.50	0.50	0.42	0.58
	601-1200	0.60	0.40	0.58	0.42	0.51	0.49
	>1200	0.90	0.10	0.90	0.10	0.51	0.49
3	<601	0.40	0.60	0.40	0.60	0.60	0.40
	601-1200	0.70	0.30	0.69	0.31	0.60	0.40
	>1200	0.92	0.08	0.91	0.09	0.89	0.11
4	<601	0.33	0.67	0.33	0.67	0.54	0.46
	601-1200	0.64	0.36	0.63	0.37	0.54	0.46
	>1200	0.97	0.03	0.96	0.04	0.94	0.06
5	<601	0.07	0.93	0.06	0.94	0.02	0.98
	601-1200	0.18	0.82	0.17	0.83	0.16	0.84
	>1200	0.84	0.16	0.83	0.17	0.83	0.17

Additional Stratification: Eastern and Western Alps

In the Swiss Alps (NFI production region 4) below an elevation of 1200 m, climate between the eastern and the western part differs substantially. An additional stratification for the eastern and the western part of the Alps below 1200 m (Alps < 601 m east, Alps < 601 m west, Alps 601-1200 m east, Alps 601-1200 m west has been included; see Thürig et al. 2005a for details). This additional stratification resulted in very small datasets per stratum.

Gains and losses in carbon stock of living biomass were estimated for the eastern and western Alps separately. The emission factors for the Alps below 1200 m were then calculated as a weighted mean of the percentage of forest biomass situated in the western and in the eastern Alps. The weights for the pooled emission factors derived from the NFI 1, NFI 2, NFI 3 and NFI 4b are listed in Table 6-14.

Table 6-14 Ratio of biomass in the eastern and western Alps (NFI production region 4) for 1985-1994 (derived from NFI 1 and NFI 2; source: Brassel and Brändli 1999), for 1995-2005 (derived from NFI 2 and NFI 3 data; source: Brändli 2010) and for 2006-2013 (derived from NFI 3 and NFI 4b data; source: Abegg et al. 2014). For NFI 4b NFI region 4 <601 m and 601-1200 m are aggregated (Thürig et al. 2015).

	1985 - 1994		1995 – 2005		2006-2013	
Altitude [m]	NFI 2 Eastern	NFI 2 Western	NFI 3 Eastern	NFI 3 Western	NFI 4b Eastern	NFI 4b Western
<601	0.56	0.44	0.53	0.47	0.60	0.40
601-1200	0.62	0.38	0.61	0.39	0.60	0.40

6.4.2.4 Estimation of Growing Stock in Biomass

The biomass of all tree compartments (stem-wood over bark including stock, coarse and small branches, needles/leaves, and roots) were estimated based on established allometries to tree-dimensions (Table 6-15; Thürig and Herold 2013). Estimates for branches, foliage and roots were derived from tree diameter at breast height (DBH). For stem-wood over bark including stock, additionally, diameter at tree height 7 m (D7) and total tree height were required. Except for roots, the biomass functions were empirically derived from a large number of single-tree data from Swiss forest sites (see references in Table 6-15).

Table 6-15 Applied allometric biomass functions, dependencies and references. DBH: tree diameter at breast height; D7: diameter at tree height 7 m.

Tree parts	Input parameter	Nr. of trees	References
Stem-wood over bark incl. stock	DBH, D7, height	12'000	Kaufmann et al. 2001
Coarse branches (>= 7 cm)	DBH	40'000	Kaufmann et al. 2001
Small branches (< 7 cm)	DBH	40'000	Kaufmann et al. 2001
Needles, Leaves	DBH	400	Perruchoud et al. 1999
Broadleaved Roots	DBH	443	Wutzler et al. 2008
Coniferous Roots	DBH	80	Zell and Thürig 2013

The biomass of all individual trees was calculated and, in a second step, single-tree estimates of gains and losses were obtained as the difference in tree biomass between subsequent NFIs (Thürig and Herold 2013).

6.4.2.5 Carbon Content

The IPCC default carbon content of solid wood of 50% was applied (IPCC 2006 Table 4.3: mean value from Lamlon and Savidge (2003) for conifers and broadleaved trees in temperate forests).

6.4.2.6 Productive Forests (CC12): Growing Stock, Gains and Losses of living biomass

Values for growing stock, gains (gross growth) and losses (cut and mortality) of living biomass for productive forests (CC12, without afforestations) were derived from 5'456 common sample plots measured during NFI 1 and NFI 2 (Kaufmann 2001), 5'581 samples measured during NFI 2 and NFI 3 (Brändli 2010) and 3'271 samples measured during NFI 3 and NFI 4b 2009-2013 (Abegg et al. 2014; Thürig et al. 2015). All values derived from the national forest inventories refer to above- and below-ground biomass in mass units (t C ha^{-1}) per spatial stratum. Table 6-16 and Table 6-17 show gains and losses of living biomass for coniferous and deciduous trees for the three intersurvey periods of NFI 1 to NFI 2, NFI 2 to NFI 3 and of NFI 3 to NFI 4b, respectively.

Table 6-16 Gains (gross growth, $gainC_l$) and losses (cut and mortality, $lossC_l$) of living biomass for coniferous trees. In the Alps (NFI production region 4) below 1200 m, data are additionally stratified for eastern and western Alps. Data sources: Brassel and Brändli (1999), Brändli (2010) and Abegg et al. (2014). Some NFI 4b strata are aggregated as described in Chapter 6.4.2.3 and in Thürig et al. (2015).

NFI region	Altitude [m]	$gainC_l$ [t C ha^{-1} yr^{-1}] NFI 1-2	$lossC_l$ [t C ha^{-1} yr^{-1}] NFI 1-2	$gainC_l$ [t C ha^{-1} yr^{-1}] NFI 2-3	$lossC_l$ [t C ha^{-1} yr^{-1}] NFI 2-3	$gainC_l$ [t C ha^{-1} yr^{-1}] NFI 3-4b	$lossC_l$ [t C ha^{-1} yr^{-1}] NFI 3-4b
1	<601	2.13	1.42	2.26	2.82	2.23	3.24
	601-1200	3.15	2.52	3.16	2.80	3.36	3.36
	>1200	2.68	2.16	2.67	1.71	2.96	1.20
2	<601	4.51	4.28	4.21	6.28	4.05	5.55
	601-1200	5.29	4.60	4.85	7.21	5.11	6.56
	>1200	2.40	1.40	1.49	2.20	5.11	6.56
3	<601	3.27	1.91	3.01	3.01	4.78	4.77
	601-1200	5.52	4.10	5.39	6.38	4.78	4.77
	>1200	4.50	3.57	4.52	4.64	5.05	3.20
4 east	<601	2.75	1.29	2.90	1.59	3.19	2.82
4 west	<601	0.72	0.84	1.23	0.92	2.18	1.66
4 east	601-1200	3.44	2.86	3.44	2.31	3.19	2.82
4 west	601-1200	2.40	2.02	2.17	1.76	2.18	1.66
4	>1200	3.36	5.59	3.50	2.43	3.51	1.88
5	<601	0.08	0.06	0.12	0.02	0.16	0.00
	601-1200	0.43	0.23	0.56	0.15	0.39	0.67
	>1200	2.38	0.75	2.46	0.78	3.27	1.03

Table 6-17 Gains (gross growth) and losses (cut and mortality) of living biomass for deciduous trees. In the Alps (NFI production region 4) below 1200 m, data are additionally stratified for eastern and western Alps. Data sources: Brassel and Brändli (1999); Brändli (2010), Abegg et al. (2014). Some NFI 4b strata are aggregated as described in Chapter 6.4.2.3 and in Thürig et al. (2015).

NFI region	Altitude [m]	$gainC_l$ [$t\ C\ ha^{-1}\ yr^{-1}$] NFI 1-2	$lossC_l$ [$t\ C\ ha^{-1}\ yr^{-1}$] NFI 1-2	$gainC_l$ [$t\ C\ ha^{-1}\ yr^{-1}$] NFI 2-3	$lossC_l$ [$t\ C\ ha^{-1}\ yr^{-1}$] NFI 2-3	$gainC_l$ [$t\ C\ ha^{-1}\ yr^{-1}$] NFI 3-4b	$lossC_l$ [$t\ C\ ha^{-1}\ yr^{-1}$] NFI 3-4b
1	<601	5.08	3.30	4.48	5.11	4.88	4.25
	601-1200	3.27	1.80	2.91	2.13	2.92	2.78
	>1200	1.22	0.31	0.93	0.57	0.78	0.45
2	<601	4.75	3.36	4.87	3.93	5.21	4.01
	601-1200	3.98	2.65	4.27	2.79	4.25	3.76
	>1200	0.80	0.16	1.07	0.40	4.25	3.76
3	<601	5.84	3.85	5.46	2.61	3.01	1.84
	601-1200	2.77	1.41	2.92	1.61	3.01	1.84
	>1200	0.46	0.12	0.48	0.11	0.50	0.18
4 east	<601	4.66	6.41	5.09	2.18	2.64	1.83
4 west	<601	5.20	3.08	4.95	2.11	2.28	1.53
4 east	601-1200	2.11	0.95	2.05	1.10	2.64	1.83
4 west	601-1200	1.93	0.73	2.27	1.03	2.28	1.53
4	>1200	0.25	0.14	0.34	0.13	0.47	0.19
5	<601	5.39	2.29	3.96	2.72	5.04	3.18
	601-1200	3.97	1.40	3.79	1.11	4.60	1.82
	>1200	0.83	0.26	1.12	0.16	0.53	0.29

Annual Gain of Living Giomass - Gross Growth

Annual values of gross growth have been derived from the NFI 1 and NFI 2 datasets for the period 1985-1994, from the NFI 2 and NFI 3 datasets for the period 1995-2005 and from the NFI 3 and NFI 4b datasets for the period 2006-2013. Annual values of gross growth are constant in the intersurvey periods of NFI 1 to NFI 2, NFI 2 to NFI 3 and of NFI 3 to NFI 4b, respectively. These annual values are averaged over 3 years (see Chapter 6.4.2.2 thereby affecting the values of gross growth of the years 1996, 1997 and 2006, 2007, respectively.

Annual Loss of Living Biomass - Cut and Mortality

An average value for cut and mortality (CM) is derived from the NFI 1 and NFI 2 dataset for the period 1985-1994, from the NFI 2 and NFI 3 datasets for the period 1995-2005 and from the NFI 3 and NFI 4b datasets for the period 2006-2013. To calculate annual values of cut and mortality (CMy) for the years 1985 to 1994, 1995 to 2005 and 2006 to 2013, respectively, the average amount of cut and mortality was weighted by the percentage of the relative harvesting amounts taken from the forest statistics (Table 6-18; FOEN 2014h and former editions 1985-2013; Swiss Federal Statistical Office: Wood production in Switzerland 1975-2013, http://www.agr-bfs.ch). Relative harvesting amounts were calculated for each year per NFI-intersurvey period. As recommended in the Revised 1996 IPCC Guidelines (IPCC 1997a), moving three-year averages of the harvesting amounts from the forest statistics were calculated in order to level out extreme events such as storm Vivian in 1990 and storm Lothar in 1999 (see Chapter 6.4.2.2).

Table 6-18 Annual harvesting amount in m^3 merchantable timber specified for five NFI production region as well as for coniferous and deciduous tree species for the period 1990-2013 (FOEN 2014h and former editions 1988-2013; http://www.agr-bfs.ch). All values were averaged over three years.

Year	1. Jura		2. Central plateau		3. Pre-Alps		4. Alps		5. Southern Alps	
	Conif.	Dec.	Conif.	Dec.	Conif.	Dec.	Conif.	Dec.	Conif.	Dec.
	[m^3]	[m^3]	[m^3]	[m^3]	[m^3]	[m^3]	[m^3]	[m^3]	[m^3]	[m^3]
1990	669'756	364'296	1'400'390	582'340	963'683	138'833	851'765	65'707	38'790	24'026
1991	616'629	360'660	1'348'951	557'776	967'684	135'699	1'002'608	68'221	31'210	24'093
1992	573'269	361'633	1'328'880	556'023	966'390	133'405	1'034'064	71'000	31'106	25'943
1993	527'672	366'516	1'141'041	541'195	779'032	131'588	816'939	68'958	38'085	29'386
1994	575'928	379'505	1'225'395	554'916	752'565	132'571	701'336	67'181	43'628	31'723
1995	607'611	391'128	1'288'507	554'563	765'351	140'962	652'879	62'517	45'047	33'467
1996	597'544	393'817	1'241'999	556'409	742'348	147'125	604'935	61'095	46'972	35'501
1997	590'296	394'443	1'210'678	571'579	723'808	152'997	557'039	60'013	53'658	37'649
1998	575'006	399'476	1'191'359	590'606	744'730	156'410	579'223	77'391	53'319	40'188
1999	602'445	405'237	1'283'404	614'399	801'259	163'971	608'468	80'428	52'075	40'285
2000	733'872	402'682	2'196'853	733'718	1'300'811	184'017	562'665	78'246	38'806	38'572
2001	680'175	374'861	2'426'715	722'713	1'514'372	181'804	513'772	62'014	29'343	36'651
2002	626'798	351'805	2'448'000	674'298	1'603'283	168'724	491'872	60'187	24'903	35'522
2003	481'195	327'776	1'698'975	535'598	1'254'485	144'789	542'312	62'065	30'195	35'667
2004	551'910	316'752	1'617'068	509'352	1'135'069	147'134	534'976	65'377	32'781	35'617
2005	622'087	326'862	1'751'762	549'665	1'108'437	162'449	530'563	67'811	34'189	34'890
2006	681'354	357'113	1'788'551	606'050	1'082'363	191'691	524'433	75'116	36'300	39'261
2007	727'255	397'149	1'726'102	667'116	1'090'739	213'537	568'604	79'224	47'235	41'950
2008	744'843	430'545	1'549'750	704'695	1'093'245	228'233	618'331	83'231	53'102	45'453
2009	699'189	448'946	1'339'493	709'282	1'013'811	226'469	654'511	85'013	57'413	43'359
2010	650'428	471'929	1'173'993	717'138	963'166	232'425	687'652	90'799	56'610	46'159
2011	621'118	489'838	1'100'727	721'806	951'347	241'980	695'223	97'139	59'529	49'219
2012	610'615	499'028	1'041'243	727'745	933'498	242'480	690'987	98'632	57'896	52'033
2013	587'138	507'823	993'813	733'257	880'742	244'671	674'158	104'655	59'347	51'663

Growing Stock: Calculation of Time Series

In order to develop a consistent time series, annual growing stocks (GS) are calculated backward or forward starting from the growing stock 2005, determined from NFI 3.

A backward calculation is used for the time period 1985-2004, meaning that the annual growing stock equals the growing stock 2005 minus the cumulated gains of the annual gross growths and plus the losses from the cumulated annual amounts of cut and mortality (CMy).

Growing stocks for inventory years after 2005 are determined using a forward calculation, i.e. adding the cumulated annual gross growths to the growing stock 2005, and subtracting the cumulated annual amounts of cut and mortality (CMy).

$$GSiy = GS2005 - \Sigma y\ [\text{annual gross growthy}] + \Sigma y\ [CMy] \quad \text{for } iy < 2005$$

$$GSiy = GS2005 \quad \text{for } iy = 2005$$

$$GSiy = GS2005 + \Sigma y\ [\text{annual gross growthy}] - \Sigma y\ [CMy] \quad \text{for } iy > 2005$$

where the “iy” indicates the inventory year and “y” refers to the years between 2005 and the inventory year.

An overview of the annual values of gross growth (gains in carbon stock of living biomass), cut and mortality (losses in carbon stock living biomass) and calculated growing stock for the period 1990 to 2013 specified for all spatial strata are displayed in Table 6-19.

All working steps and data required to reproduce the calculation of emission factors for productive forests (CC12) in the period 1990-2013 are summarized in FOEN (2015b).

Table 6-19 Annual carbon data of living biomass for productive forest (CC12) disaggregated for NFI region (NFI) and altitude zone (Alt.), 1990-2013, three-year-averages for gains (gross growth) and losses (cut and mortality) of living biomass. Highlighted data for 1990 are displayed in Table 6-4.

NFI	Alt.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
		CC12: carbon stock in living biomass (stockCl,i) [t C ha^{-1}]									
1	1	126.87	128.07	129.34	130.66	132.01	133.24	134.39	133.80	133.14	132.41
1	2	124.88	125.82	126.88	128.02	129.25	130.35	131.35	131.98	132.58	133.13
1	3	84.73	85.35	86.06	86.85	87.72	88.50	89.21	89.97	90.68	91.36
2	1	134.18	134.69	135.35	136.06	137.13	138.01	138.79	139.29	139.78	140.21
2	2	146.77	147.47	148.33	149.22	150.49	151.58	152.55	153.26	153.97	154.66
2	3	101.21	101.95	102.72	103.51	104.40	105.24	106.05	106.56	106.97	107.29
3	1	135.06	136.58	138.13	139.71	141.54	143.38	145.08	147.32	149.42	151.36
3	2	147.43	148.52	149.61	150.72	152.30	153.93	155.49	156.74	158.01	159.21
3	3	119.32	119.69	120.06	120.43	121.20	122.02	122.82	123.67	124.57	125.44
4	1	94.81	95.34	95.69	95.92	96.37	96.96	97.88	99.57	101.40	102.99
4	2	104.42	105.10	105.52	105.87	106.59	107.51	108.45	109.33	110.32	111.14
4	3	96.41	96.60	96.50	96.34	96.59	97.06	97.61	98.11	98.75	99.35
5	1	70.67	72.40	74.13	75.78	77.29	78.70	80.03	81.22	82.10	82.65
5	2	76.70	78.18	79.69	81.15	82.50	83.78	85.01	86.58	88.10	89.58
5	3	76.70	77.83	79.03	80.22	81.33	82.38	83.40	84.53	85.65	86.82

NFI	Alt.	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
		CC12: carbon stock in living biomass (stockCl,i) [t C ha^{-1}]									
1	1	131.57	130.45	129.64	129.12	129.10	128.99	129.08	128.93	128.64	128.37
1	2	133.61	133.79	134.17	134.74	135.72	136.57	136.82	136.86	136.79	136.77
1	3	92.00	92.46	93.01	93.66	94.52	95.30	96.34	97.33	98.33	99.35
2	1	140.40	138.51	136.24	134.09	133.77	133.68	132.79	131.88	131.26	131.06
2	2	155.10	153.34	151.11	148.95	148.70	148.67	146.16	144.74	143.73	143.21
2	3	107.54	107.16	106.64	106.12	106.12	106.19	146.16	144.74	143.73	143.21
3	1	153.16	154.11	154.78	155.44	156.77	158.25	157.75	158.27	158.64	159.20
3	2	160.20	159.64	158.47	157.10	156.87	156.97	157.75	158.27	158.64	159.20
3	3	126.18	125.85	125.07	124.10	123.89	123.92	124.71	125.56	126.50	127.57
4	1	104.50	106.09	107.99	109.95	111.82	113.65	117.83	118.66	119.36	119.99
4	2	111.87	112.71	113.77	114.88	115.89	116.88	117.83	118.66	119.36	119.99
4	3	99.89	100.53	101.29	102.09	102.78	103.49	104.59	105.66	106.68	107.64
5	1	83.20	83.82	84.51	85.24	85.97	86.70	87.58	88.54	89.58	90.68
5	2	91.06	92.59	94.16	95.76	97.35	98.93	100.22	101.49	102.76	104.04
5	3	88.01	89.33	90.75	92.22	93.63	95.02	96.37	97.65	98.89	100.10

NFI	Alt.	2010	2011	2012	2013						
		CC12: carbon stock in living biomass (stockCl,i) [t C ha^{-1}]									
1	1	128.11	127.84	127.55	127.27						
1	2	136.81	136.87	136.93	137.02						
1	3	100.40	101.48	102.55	103.65						
2	1	131.18	131.44	131.81	132.26						
2	2	143.08	143.12	143.29	143.56						
2	3	143.08	143.12	143.29	143.56						
3	1	159.86	160.52	161.21	162.02						
3	2	159.86	160.52	161.21	162.02						
3	3	128.71	129.87	131.06	132.33						
4	1	120.49	120.93	121.36	121.76						
4	2	120.49	120.93	121.36	121.76						
4	3	108.55	109.45	110.35	111.27						
5	1	91.69	92.59	93.40	94.22						
5	2	105.27	106.43	107.54	108.65						
5	3	101.31	102.48	103.66	104.82						

(Table 6-19 continued)

NFI	Alt.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
		CC12: gain of living biomass (gainCl,i) [t C ha^{-1} yr^{-1}]									
1	1	3.60	3.60	3.60	3.60	3.60	3.60	3.53	3.45	3.37	3.37
1	2	3.21	3.21	3.21	3.21	3.21	3.21	3.15	3.09	3.04	3.04
1	3	1.95	1.95	1.95	1.95	1.95	1.95	1.90	1.85	1.80	1.80
2	1	4.63	4.63	4.63	4.63	4.63	4.63	4.60	4.57	4.54	4.54
2	2	4.63	4.63	4.63	4.63	4.63	4.63	4.61	4.59	4.56	4.56
2	3	1.60	1.60	1.60	1.60	1.60	1.60	1.49	1.39	1.28	1.28
3	1	4.56	4.56	4.56	4.56	4.56	4.56	4.45	4.34	4.23	4.23
3	2	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15
3	3	2.48	2.48	2.48	2.48	2.48	2.48	2.49	2.49	2.50	2.50
4	1	3.24	3.24	3.24	3.24	3.24	3.24	3.31	3.37	3.44	3.44
4	2	2.49	2.49	2.49	2.49	2.49	2.49	2.50	2.50	2.50	2.50
4	3	1.81	1.81	1.81	1.81	1.81	1.81	1.84	1.87	1.90	1.90
5	1	2.74	2.74	2.74	2.74	2.74	2.74	2.51	2.27	2.04	2.04
5	2	2.20	2.20	2.20	2.20	2.20	2.20	2.19	2.18	2.18	2.18
5	3	1.61	1.61	1.61	1.61	1.61	1.61	1.67	1.73	1.79	1.79

NFI	Alt.	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
		CC12: gain of living biomass (gainCl,i) [t C ha^{-1} yr^{-1}]									
1	1	3.37	3.37	3.37	3.37	3.37	3.37	3.43	3.49	3.55	3.55
1	2	3.04	3.04	3.04	3.04	3.04	3.04	3.07	3.11	3.14	3.14
1	3	1.80	1.80	1.80	1.80	1.80	1.80	1.83	1.85	1.87	1.87
2	1	4.54	4.54	4.54	4.54	4.54	4.54	4.57	4.60	4.63	4.63
2	2	4.56	4.56	4.56	4.56	4.56	4.48	4.55	4.61	4.68	4.68
2	3	1.28	1.28	1.28	1.28	1.28	4.48	4.55	4.61	4.68	4.68
3	1	4.23	4.23	4.23	4.23	4.23	4.16	4.07	3.98	3.89	3.89
3	2	4.15	4.15	4.15	4.15	4.15	4.16	4.07	3.98	3.89	3.89
3	3	2.50	2.50	2.50	2.50	2.50	2.50	2.59	2.68	2.78	2.78
4	1	3.44	3.44	3.44	3.44	3.44	2.59	2.55	2.59	2.60	2.60
4	2	2.50	2.50	2.50	2.50	2.50	2.59	2.55	2.59	2.60	2.60
4	3	1.90	1.90	1.90	1.90	1.90	1.90	1.93	1.96	1.99	1.99
5	1	2.04	2.04	2.04	2.04	2.04	2.04	2.23	2.41	2.60	2.60
5	2	2.18	2.18	2.18	2.18	2.18	2.18	2.28	2.39	2.50	2.50
5	3	1.79	1.79	1.79	1.79	1.79	1.79	1.83	1.86	1.90	1.90

NFI	Alt.	2010	2011	2012	2013						
		CC12: gain of living biomass (gainCl,i) [t C ha^{-1} yr^{-1}]									
1	1	3.55	3.55	3.55	3.55						
1	2	3.14	3.14	3.14	3.14						
1	3	1.87	1.87	1.87	1.87						
2	1	4.63	4.63	4.63	4.63						
2	2	4.68	4.68	4.68	4.68						
2	3	4.68	4.68	4.68	4.68						
3	1	3.89	3.89	3.89	3.89						
3	2	3.89	3.89	3.89	3.89						
3	3	2.78	2.78	2.78	2.78						
4	1	2.60	2.60	2.60	2.60						
4	2	2.60	2.60	2.60	2.60						
4	3	1.99	1.99	1.99	1.99						
5	1	2.60	2.60	2.60	2.60						
5	2	2.50	2.50	2.50	2.50						
5	3	1.90	1.90	1.90	1.90						

(Table 6-19 continued)

NFI	Alt.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
		CC12: loss of living biomass (lossCl,i) [t C ha^{-1} yr^{-1}]									
1	1	-2.41	-2.33	-2.29	-2.25	-2.37	-2.46	-4.12	-4.10	-4.10	-4.21
1	2	-2.27	-2.15	-2.07	-1.98	-2.11	-2.21	-2.52	-2.50	-2.48	-2.56
1	3	-1.34	-1.24	-1.16	-1.09	-1.18	-1.24	-1.15	-1.14	-1.12	-1.16
2	1	-4.13	-3.97	-3.93	-3.56	-3.75	-3.85	-4.09	-4.08	-4.11	-4.36
2	2	-3.93	-3.78	-3.74	-3.36	-3.55	-3.66	-3.90	-3.87	-3.88	-4.12
2	3	-0.86	-0.82	-0.81	-0.71	-0.76	-0.79	-0.98	-0.97	-0.96	-1.03
3	1	-3.04	-3.00	-2.97	-2.73	-2.72	-2.85	-2.22	-2.24	-2.29	-2.43
3	2	-3.06	-3.05	-3.04	-2.57	-2.51	-2.59	-2.90	-2.88	-2.96	-3.16
3	3	-2.11	-2.11	-2.11	-1.71	-1.66	-1.69	-1.63	-1.59	-1.64	-1.76
4	1	-2.71	-2.89	-3.01	-2.79	-2.66	-2.47	-1.62	-1.55	-1.85	-1.93
4	2	-1.81	-2.07	-2.14	-1.77	-1.57	-1.47	-1.61	-1.51	-1.69	-1.77
4	3	-1.62	-1.91	-1.97	-1.56	-1.34	-1.25	-1.34	-1.23	-1.29	-1.36
5	1	-1.01	-1.01	-1.08	-1.23	-1.33	-1.40	-1.32	-1.40	-1.49	-1.49
5	2	-0.71	-0.69	-0.74	-0.84	-0.92	-0.97	-0.62	-0.66	-0.70	-0.70
5	3	-0.48	-0.41	-0.41	-0.50	-0.56	-0.58	-0.54	-0.61	-0.61	-0.60

NFI	Alt.	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
		CC12: loss of living biomass (lossCl,i) [t C ha^{-1} yr^{-1}]									
1	1	-4.49	-4.18	-3.89	-3.39	-3.48	-3.71	-3.34	-3.64	-3.84	-3.82
1	2	-2.86	-2.65	-2.46	-2.06	-2.19	-2.38	-2.83	-3.07	-3.21	-3.15
1	3	-1.35	-1.25	-1.16	-0.93	-1.02	-1.13	-0.79	-0.85	-0.88	-0.85
2	1	-6.42	-6.81	-6.69	-4.86	-4.63	-5.01	-5.46	-5.51	-5.25	-4.83
2	2	-6.33	-6.79	-6.72	-4.82	-4.59	-4.87	-6.01	-6.03	-5.70	-5.19
2	3	-1.66	-1.80	-1.80	-1.27	-1.21	-4.87	-6.01	-6.03	-5.70	-5.19
3	1	-3.28	-3.56	-3.58	-2.90	-2.76	-4.00	-3.35	-3.46	-3.53	-3.33
3	2	-4.72	-5.33	-5.52	-4.39	-4.05	-4.00	-3.35	-3.46	-3.53	-3.33
3	3	-2.83	-3.28	-3.46	-2.72	-2.46	-2.41	-1.81	-1.83	-1.84	-1.71
4	1	-1.84	-1.53	-1.48	-1.56	-1.61	-1.53	-1.65	-1.76	-1.89	-1.97
4	2	-1.66	-1.44	-1.39	-1.50	-1.51	-1.53	-1.65	-1.76	-1.89	-1.97
4	3	-1.26	-1.14	-1.09	-1.20	-1.19	-1.18	-0.83	-0.90	-0.97	-1.03
5	1	-1.43	-1.35	-1.31	-1.32	-1.32	-1.29	-1.35	-1.45	-1.57	-1.49
5	2	-0.65	-0.60	-0.58	-0.59	-0.59	-0.59	-1.00	-1.12	-1.23	-1.21
5	3	-0.47	-0.37	-0.32	-0.38	-0.40	-0.41	-0.47	-0.59	-0.65	-0.69

NFI	Alt.	2010	2011	2012	2013						
		CC12: loss of living biomass (lossCl,i) [t C ha^{-1} yr^{-1}]									
1	1	-3.81	-3.82	-3.84	-3.83						
1	2	-3.10	-3.08	-3.09	-3.88						
1	3	-0.82	-0.80	-0.80	-3.05						
2	1	-4.51	-4.37	-4.26	-2.10						
2	2	-4.81	-4.64	-4.51	-0.82						
2	3	-4.81	-4.64	-4.51	-0.82						
3	1	-3.23	-3.24	-3.20	-4.59						
3	2	-3.23	-3.24	-3.20	-4.59						
3	3	-1.63	-1.62	-1.59	-4.51						
4	1	-2.09	-2.16	-2.17	-0.59						
4	2	-2.09	-2.16	-2.17	-0.59						
4	3	-1.08	-1.10	-1.09	-0.79						
5	1	-1.59	-1.70	-1.79	-3.36						
5	2	-1.26	-1.34	-1.39	-4.73						
5	3	-0.69	-0.73	-0.72	-3.07						

Separation of Above and Belowground Living Biomass

Carbon stock of total living biomass can be separated using the ratios listed in Table 6-20 . Under the UNFCCC both pools are merged, under the Kyoto Protocol the pools are reported separately (see Chapter 11.3.1.1). For forest management, the stratified values in Table 6-20 were used. For afforestation and deforestation the Swiss mean value (0.30) was used.

Table 6-20 Root-to-shoot ratios to separate total living biomass into above and belowground living biomass. The ratios are retrieved from the NFI (Brändli 2010: Table 095).

NFI region	Altitude [m]	Root-to-shoot ratios for living trees
1	<601	0.22
	601-1200	0.27
	>1200	0.35
2	<601	0.22
	601-1200	0.24
	>1200	0.40
3	<601	0.23
	601-1200	0.28
	>1200	0.37
4	<601	0.25
	601-1200	0.30
	>1200	0.40
5	<601	0.28
	601-1200	0.32
	>1200	0.40
Switzerland	<601	0.23
	601-1200	0.27
	>1200	0.39
	average	0.30

6.4.2.7 Productive Forests (CC12): Carbon Stocks in Dead Wood, Litter and in Soils

Dead Wood - Carbon Stock

The influence of wood decay on wood density and on carbon content of dead wood was investigated by Dobbertin and Jüngling (2009) for two dominant tree species in Swiss forests: Norway spruce (Picea abies) and beech (Fagus sylvatica). They found a significant decrease in relative wood density with increasing decay stage for Norway spruce (30%) and beech (60%) compared to fresh wood. Only small differences in carbon content in dry matter were found between tree species and between fresh wood and dead wood (1.2 - 1.4%), but carbon content remained stable regardless of the decay stage and the species.

The total amount of carbon in the total dead wood pool (TDW) in Switzerland consists of three components:

TDW = CWD + LIS + DRoots

where

- CWD (coarse woody debris) contains all wood of dead trees with a diameter of at least 12 cm,
- LIS contains lying small diameter dead wood with a diameter of at least 7 cm determined with the line intersect method and
- DRoots consist of dead coarse roots.

A time series of carbon stocks in dead wood was simulated with the soil carbon model Yasso07 (Didion et al. 2014; see description in Chapter 6.4.2.8). Stratified estimated dead wood stocks for 1990 are shown in Table 6-21. Annual values for dead wood stocks since 1990 are displayed in Table 6-22.

Soil and Litter (Organic Soil Horizons) in Mineral Soils - Carbon Stock

Nussbaum et al. (2012, 2014) provided updated data for carbon stocks of litter (organic soil horizons L - litter, F - fermentation and H - humus) and soil organic carbon in Swiss forests. 1033 sites of a database stored at WSL distributed among different forest types throughout Switzerland were chosen for this study. Further information on the carbon content of L horizons was taken from Moeri (2007). By using this dataset and robust geostatistical methods, the authors produced a map of organic carbon stocks of Swiss forest soils. The data for litter and soil carbon stocks are stratified by the five NFI production regions and three elevation levels (Table 6-21).

The WSL soil database sites that were used in this study were visited mostly between 1990 and 2005. It is not possible to attribute these carbon stocks to one single year. Therefore, the values from Nussbaum et al. (2012, 2014) are assumed to be representative for the period 1990-2013. In the organic soil horizons (litter) of mineral soils in productive and unproductive forests an average carbon stock of 16.7 t C ha^{-1} was estimated. In the same study, an average carbon stock in mineral forest soils of 79.9 t C ha^{-1} in 0-30 cm topsoil was estimated.

Table 6-21 Dead wood stock (TDW) in Swiss productive forests (CC12) with diameter >7 cm by spatial stratum in t C ha^{-1} for 1990 (Didion et al. 2014). NFI region 2, 601-1200 and > 1200 m are aggregated. Carbon stock in organic soil horizons (litter; used for CC12, CC13) and in soil organic carbon (used for CC11, CC12, CC13) in mineral soil horizons (0-30 cm) of forest soils are assumed to be representative for 1990-2013. The data are stratified by five NFI production regions and three elevation levels (Nussbaum et al. 2012, 2014). Average values ± standard error are given.

NFI region	**Altitude [m]**	**Carbon stock in dead wood 1990 ($stockC_{d,i,12}$) [t C ha^{-1}]**	**Carbon stock in litter ($stockC_{h,i,12}$, $stockC_{h,i,13}$) [t C ha^{-1}]**	**Carbon stock in mineral topsoil 0-30 cm ($stockC_{s,i,11}$, $stockC_{s,i,12}$, $stockC_{s,i,13}$) [t C ha^{-1}]**
1	<601	5.84 ± 0.08	9.51 ± 1.57	82.65 ± 3.34
1	601-1200	6.08 ± 0.06	7.53 ± 0.70	102.03 ± 3.56
1	>1200	6.51 ± 0.17	7.76 ± 1.74	121.34 ± 5.39
2	<601	9.22 ± 0.08	8.70 ± 0.68	55.40 ± 1.55
2	601-1200	8.99 ± 0.10	11.42 ± 1.45	62.12 ± 1.68
2	>1200	8.99 ± 0.10	11.42 ± 1.45	122.00 ± 7.07
3	<601	10.36 ± 0.40	7.51 ± 1.25	66.10 ± 2.06
3	601-1200	9.46 ± 0.09	16.29 ± 1.55	57.91 ± 2.00
3	>1200	8.18 ± 0.12	26.21 ± 4.77	95.78 ± 3.27
4	<601	8.12 ± 0.29	3.15 ± 0.47	66.47 ± 2.44
4	601-1200	8.05 ± 0.09	19.99 ± 2.64	74.39 ± 2.42
4	>1200	7.91 ± 0.07	33.37 ± 3.53	69.48 ± 1.85
5	<601	2.99 ± 0.07	8.22 ± 1.62	102.37 ± 4.07
5	601-1200	3.29 ± 0.06	11.03 ± 2.11	108.99 ± 4.09
5	>1200	3.01 ± 0.05	30.77 ± 5.43	107.08 ± 4.11
Switzerland		7.57 ± 0.03	16.73 ± 0.83	79.93 ± 1.52

Table 6-22 Carbon stock in dead wood for CC12, 1990-2013. Highlighted data for 1990 are displayed in Table 6-4.

NFI	Alt.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
		CC12: carbon stock in dead wood (stockCd,i) [t C ha^{-1}]									
1	1	5.84	5.84	5.84	5.85	5.83	5.82	5.86	5.99	6.24	6.53
1	2	6.08	6.04	6.00	5.98	5.93	5.90	5.88	5.88	5.91	5.94
1	3	6.51	6.55	6.59	6.63	6.65	6.67	6.67	6.61	6.46	6.26
2	1	9.22	9.18	9.14	9.11	9.06	9.00	9.00	9.09	9.27	9.49
2	2	8.99	8.96	8.93	8.91	8.86	8.82	8.83	8.95	9.17	9.44
2	3	8.99	8.96	8.93	8.91	8.86	8.82	8.83	8.95	9.17	9.44
3	1	10.36	10.64	10.88	11.10	11.28	11.43	11.53	11.52	11.35	11.07
3	2	9.46	9.47	9.48	9.49	9.48	9.48	9.54	9.70	10.00	10.37
3	3	8.18	8.01	7.85	7.71	7.57	7.44	7.33	7.23	7.14	7.05
4	1	8.12	8.38	8.61	8.83	9.00	9.16	9.26	9.28	9.15	8.94
4	2	8.05	7.97	7.89	7.82	7.75	7.68	7.63	7.58	7.55	7.52
4	3	7.91	7.93	7.94	7.95	7.95	7.95	7.95	7.94	7.89	7.81
5	1	2.99	2.87	2.77	2.68	2.60	2.52	2.45	2.38	2.33	2.28
5	2	3.29	3.37	3.45	3.52	3.58	3.63	3.65	3.60	3.46	3.26
5	3	3.01	2.96	2.92	2.89	2.85	2.82	2.79	2.76	2.72	2.69

NFI	Alt.	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
		CC12: carbon stock in dead wood (stockCd,i) [t C ha^{-1}]									
1	1	6.83	7.10	7.33	7.57	7.79	8.01	8.19	8.35	8.49	8.61
1	2	5.98	6.00	6.02	6.05	6.08	6.11	6.16	6.24	6.36	6.51
1	3	6.04	5.84	5.66	5.49	5.34	5.21	5.08	4.94	4.78	4.63
2	1	9.71	9.89	10.05	10.23	10.40	10.57	10.71	10.83	10.91	10.99
2	2	9.71	9.95	10.16	10.38	10.58	10.78	10.96	11.13	11.28	11.43
2	3	9.71	9.95	10.16	10.38	10.58	10.78	10.96	11.13	11.28	11.43
3	1	10.75	10.47	10.21	9.99	9.80	9.64	9.58	9.69	10.05	10.54
3	2	10.75	11.10	11.41	11.70	11.97	12.24	12.47	12.61	12.67	12.68
3	3	6.98	6.91	6.83	6.76	6.70	6.65	6.62	6.60	6.61	6.65
4	1	8.71	8.49	8.30	8.13	7.99	7.87	7.82	7.86	8.05	8.32
4	2	7.48	7.45	7.41	7.38	7.36	7.35	7.36	7.38	7.42	7.49
4	3	7.73	7.65	7.57	7.51	7.45	7.41	7.38	7.36	7.35	7.36
5	1	2.23	2.18	2.14	2.11	2.08	2.05	2.04	2.06	2.10	2.17
5	2	3.06	2.87	2.70	2.56	2.42	2.30	2.21	2.15	2.14	2.16
5	3	2.65	2.62	2.59	2.56	2.53	2.52	2.53	2.58	2.70	2.86

NFI	Alt.	2010	2011	2012	2013						
		CC12: carbon stock in dead wood (stockCd,i) [t C ha^{-1}]									
1	1	8.75	8.89	9.01	9.11						
1	2	6.69	6.85	6.99	7.11						
1	3	4.50	4.37	4.25	4.13						
2	1	11.09	11.18	11.27	11.34						
2	2	11.60	11.76	11.91	12.03						
2	3	11.60	11.76	11.91	12.03						
3	1	11.08	11.54	11.96	12.33						
3	2	12.70	12.71	12.72	12.73						
3	3	6.70	6.74	6.78	6.81						
4	1	8.65	8.94	9.20	9.43						
4	2	7.57	7.64	7.71	7.76						
4	3	7.38	7.40	7.41	7.42						
5	1	2.25	2.32	2.39	2.45						
5	2	2.21	2.24	2.28	2.31						
5	3	3.04	3.20	3.35	3.48						

6.4.2.8 Productive Forests (CC12): Changes in Carbon Stocks in Dead Wood, in Litter and in Mineral Soils

Switzerland used the soil carbon model Yasso07 to estimate temporal changes in carbon stocks in soil organic carbon, organic soil horizons (LFH; litter) and in dead wood (TDW) for productive forests (CC12). The implementation of Yasso07 (Tuomi et al. 2009, 2011) in the Swiss GHG inventory is described in detail in Didion et al. (2012, 2013, 2014). Didion et al. (2014a) demonstrated the validity of the model for application in Swiss forests.

Yasso07 is a model of carbon cycling in mineral soil, litter and dead wood. For estimating stocks of organic carbon in mineral soil up to a depth of ca. 100 cm and the temporal dynamics of the carbon stocks, Yasso07 requires information on carbon inputs from dead organic matter (i.e. non-woody inputs, including foliage and fine roots, woody inputs, including standing and lying dead wood and dead roots) and climate (temperature, temperature amplitude and precipitation).

By default, Yasso07 does not provide separate estimates of carbon pool sizes for dead wood, litter and soil. In order to report estimates for each pool, the structure of Yasso07 was examined for deriving separate estimates (Didion et al. 2012, 2013, 2014). Dead wood, litter and soil pools could be correlated with modeled data based on the category of carbon input, i.e., non-woody and woody material, and the five carbon compartments in Yasso07, i.e. four chemical partitions (insoluble, soluble in ethanol, soluble in water or in acid and humus). The approach was validated using independent, measured data (see Didion et al. 2012).

Using annual data for climate and for carbon inputs obtained from the Swiss NFIs, Yasso07 was used for estimating the annual carbon stock changes in mineral soil, litter and dead wood. Annual carbon stock changes were calculated from carbon Yasso-stocks that were averaged over three years following the recommendation in IPCC (2003; Chapter 6.4.2.2). For an overview, Figure 6-5 shows the mean stock changes in Swiss forests for these three carbon pools (mineral soil, litter, dead wood) and the aggregated total. Annual stratified values for CC12 can be found in Table 6-23 Carbon stocks and carbon stock changes were validated as described in Didion et al. (2014).

Table 6-23 Net carbon stock change in dead wood, in litter, and in mineral soils for productive forest (CC12), 1990-2013. Highlighted data for 1990 are displayed in Table 6-4.

NFI	Alt.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
		CC12: net change in dead wood (changeCd,i) [t C ha^{-1} yr^{-1}]									
1	1	-0.01	0.01	0.00	0.01	-0.01	-0.02	0.04	0.13	0.25	0.30
1	2	-0.05	-0.04	-0.04	-0.03	-0.04	-0.04	-0.02	0.01	0.03	0.03
1	3	0.04	0.04	0.04	0.04	0.02	0.02	0.00	-0.06	-0.15	-0.20
2	1	-0.07	-0.04	-0.04	-0.03	-0.06	-0.06	0.00	0.09	0.19	0.22
2	2	-0.05	-0.03	-0.03	-0.02	-0.04	-0.04	0.01	0.11	0.23	0.27
2	3	-0.05	-0.03	-0.03	-0.02	-0.04	-0.04	0.01	0.11	0.23	0.27
3	1	0.29	0.27	0.24	0.22	0.17	0.15	0.10	0.00	-0.17	-0.28
3	2	0.00	0.01	0.01	0.02	-0.01	-0.01	0.06	0.16	0.30	0.37
3	3	-0.20	-0.17	-0.16	-0.14	-0.14	-0.13	-0.11	-0.10	-0.09	-0.09
4	1	0.28	0.26	0.23	0.21	0.17	0.16	0.10	0.01	-0.12	-0.21
4	2	-0.09	-0.08	-0.08	-0.07	-0.08	-0.07	-0.05	-0.04	-0.03	-0.04
4	3	0.01	0.01	0.01	0.01	0.00	0.01	0.00	-0.02	-0.05	-0.07
5	1	-0.13	-0.11	-0.10	-0.09	-0.09	-0.08	-0.07	-0.06	-0.06	-0.05
5	2	0.09	0.08	0.08	0.07	0.06	0.06	0.02	-0.05	-0.14	-0.20
5	3	-0.05	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03	-0.04

NFI	Alt.	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
		CC12: net change in dead wood (changeCd,i) [t C ha^{-1} yr^{-1}]									
1	1	0.30	0.26	0.23	0.24	0.22	0.22	0.18	0.16	0.13	0.13
1	2	0.03	0.03	0.02	0.03	0.03	0.04	0.05	0.07	0.12	0.15
1	3	-0.22	-0.20	-0.18	-0.17	-0.15	-0.13	-0.13	-0.14	-0.15	-0.15
2	1	0.22	0.18	0.16	0.17	0.17	0.18	0.14	0.11	0.08	0.08
2	2	0.27	0.24	0.21	0.21	0.20	0.21	0.18	0.16	0.15	0.15
2	3	0.27	0.24	0.21	0.21	0.20	0.21	0.18	0.16	0.15	0.15
3	1	-0.32	-0.28	-0.26	-0.22	-0.19	-0.16	-0.06	0.11	0.36	0.49
3	2	0.38	0.35	0.31	0.29	0.27	0.27	0.22	0.15	0.06	0.01
3	3	-0.08	-0.07	-0.07	-0.07	-0.06	-0.05	-0.03	-0.02	0.01	0.03
4	1	-0.23	-0.21	-0.19	-0.17	-0.15	-0.11	-0.06	0.04	0.19	0.27
4	2	-0.03	-0.03	-0.04	-0.03	-0.02	-0.01	0.01	0.02	0.04	0.06
4	3	-0.08	-0.08	-0.08	-0.07	-0.06	-0.04	-0.03	-0.02	-0.01	0.01
5	1	-0.05	-0.04	-0.04	-0.03	-0.03	-0.03	-0.01	0.02	0.05	0.07
5	2	-0.21	-0.18	-0.17	-0.15	-0.14	-0.12	-0.09	-0.06	-0.01	0.02
5	3	-0.04	-0.03	-0.03	-0.03	-0.03	-0.02	0.01	0.06	0.12	0.16

NFI	Alt.	2010	2011	2012	2013						
		CC12: net change in dead wood (changeCd,i) [t C ha^{-1} yr^{-1}]									
1	1	0.14	0.13	0.12	0.10						
1	2	0.18	0.16	0.14	0.12						
1	3	-0.13	-0.13	-0.12	-0.11						
2	1	0.10	0.10	0.09	0.07						
2	2	0.18	0.16	0.14	0.12						
2	3	0.18	0.16	0.14	0.12						
3	1	0.54	0.47	0.42	0.37						
3	2	0.02	0.01	0.01	0.00						
3	3	0.06	0.04	0.04	0.03						
4	1	0.32	0.29	0.26	0.23						
4	2	0.09	0.07	0.06	0.05						
4	3	0.03	0.02	0.01	0.00						
5	1	0.08	0.07	0.07	0.06						
5	2	0.04	0.04	0.04	0.03						
5	3	0.18	0.16	0.15	0.13						

(Table 6-23 continued)

NFI	Alt.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
		CC12: net change in litter (changeCh,i) [t C ha^{-1} yr^{-1}]									
1	1	-0.08	0.01	-0.02	0.01	-0.07	-0.07	-0.01	0.08	0.10	0.04
1	2	-0.08	-0.02	-0.02	0.00	-0.07	-0.05	0.01	0.08	0.11	0.08
1	3	-0.26	-0.18	-0.14	-0.10	-0.13	-0.09	-0.05	-0.02	0.00	-0.02
2	1	-0.13	-0.03	-0.05	-0.02	-0.09	-0.08	-0.02	0.07	0.10	0.05
2	2	-0.02	0.05	0.02	0.04	-0.05	-0.04	0.02	0.09	0.11	0.06
2	3	-0.02	0.05	0.02	0.04	-0.05	-0.04	0.02	0.09	0.11	0.06
3	1	0.25	0.25	0.20	0.17	0.06	0.04	0.05	0.06	-0.01	-0.08
3	2	-0.10	-0.05	-0.03	-0.01	-0.08	-0.05	0.01	0.07	0.10	0.08
3	3	-0.14	-0.10	-0.07	-0.04	-0.10	-0.05	0.01	0.07	0.13	0.13
4	1	-0.03	0.02	-0.01	0.00	-0.06	-0.05	-0.02	0.01	0.01	-0.02
4	2	-0.08	-0.04	-0.05	-0.03	-0.09	-0.05	0.00	0.04	0.06	0.03
4	3	-0.04	-0.01	-0.04	-0.02	-0.09	-0.03	0.01	0.07	0.11	0.07
5	1	-0.27	-0.19	-0.15	-0.12	-0.12	-0.08	-0.01	0.08	0.19	0.23
5	2	-0.29	-0.21	-0.17	-0.14	-0.13	-0.09	-0.03	0.05	0.13	0.16
5	3	0.04	0.04	0.03	0.03	-0.02	0.02	0.08	0.14	0.21	0.21

NFI	Alt.	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
		CC12: net change in litter (changeCh,i) [t C ha^{-1} yr^{-1}]									
1	1	0.01	-0.01	-0.02	0.06	0.06	0.11	0.00	-0.08	-0.16	-0.16
1	2	0.06	0.04	0.02	0.06	0.05	0.09	0.04	-0.01	-0.04	-0.02
1	3	-0.01	-0.01	-0.03	-0.01	-0.01	0.03	0.02	0.00	0.00	0.02
2	1	0.01	-0.01	-0.02	0.05	0.06	0.10	0.01	-0.06	-0.14	-0.14
2	2	0.03	0.01	-0.01	0.05	0.05	0.10	0.02	-0.06	-0.14	-0.15
2	3	0.03	0.01	-0.01	0.05	0.05	0.10	0.02	-0.06	-0.14	-0.15
3	1	-0.10	-0.08	-0.09	-0.02	-0.01	0.05	0.04	0.02	0.02	0.02
3	2	0.07	0.05	0.01	0.04	0.03	0.08	0.03	-0.05	-0.13	-0.13
3	3	0.14	0.11	0.05	0.05	0.04	0.10	0.05	-0.03	-0.12	-0.11
4	1	-0.02	-0.03	-0.05	0.00	0.01	0.07	0.04	0.01	-0.01	0.01
4	2	0.03	0.01	-0.02	0.02	0.03	0.10	0.07	0.01	-0.05	-0.04
4	3	0.05	0.02	-0.01	0.03	0.06	0.15	0.09	0.01	-0.07	-0.05
5	1	0.22	0.18	0.13	0.14	0.10	0.13	0.11	0.08	0.03	0.02
5	2	0.16	0.13	0.09	0.10	0.07	0.12	0.11	0.10	0.09	0.09
5	3	0.21	0.18	0.11	0.13	0.10	0.19	0.15	0.12	0.05	0.07

NFI	Alt.	2010	2011	2012	2013						
		CC12: net change in litter (changeCh,i) [t C ha^{-1} yr^{-1}]									
1	1	-0.08	-0.06	-0.06	-0.07						
1	2	0.05	0.02	0.01	-0.01						
1	3	0.08	0.03	0.03	0.01						
2	1	-0.06	-0.04	-0.04	-0.05						
2	2	-0.06	-0.05	-0.04	-0.06						
2	3	-0.06	-0.05	-0.04	-0.06						
3	1	0.10	0.06	0.05	0.03						
3	2	-0.05	-0.07	-0.06	-0.07						
3	3	-0.04	-0.08	-0.07	-0.08						
4	1	0.08	0.05	0.04	0.01						
4	2	0.04	0.01	0.00	-0.03						
4	3	0.04	0.00	-0.03	-0.07						
5	1	0.06	0.05	0.04	0.01						
5	2	0.14	0.09	0.08	0.03						
5	3	0.15	0.08	0.06	0.00						

(Table 6-23 continued)

NFI	Alt.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
		CC12: net change in mineral soil (changeCs,i) [t C ha^{-1} yr^{-1}]									
1	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
1	2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	3	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
2	1	0.000	0.000	0.000	0.000	0.000	-0.001	-0.001	-0.001	0.000	0.000
2	2	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
2	3	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
3	1	0.002	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.004
3	2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
3	3	0.000	0.000	0.000	0.000	0.000	-0.001	-0.001	-0.001	0.000	0.000
4	1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
4	2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	3	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
5	1	-0.001	-0.002	-0.002	-0.002	-0.002	-0.003	-0.003	-0.003	-0.002	-0.002
5	2	-0.001	-0.001	-0.001	-0.001	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
5	3	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002

NFI	Alt.	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
		CC12: net change in mineral soil (changeCs,i) [t C ha^{-1} yr^{-1}]									
1	1	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.001
1	2	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1	3	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
2	1	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000
2	2	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
2	3	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
3	1	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
3	2	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002
3	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
4	2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	3	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
5	1	-0.002	-0.002	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	0.000
5	2	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
5	3	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.004

NFI	Alt.	2010	2011	2012	2013						
		CC12: net change in mineral soil (changeCs,i) [t C ha^{-1} yr^{-1}]									
1	1	0.001	0.001	0.001	0.001						
1	2	0.001	0.001	0.001	0.001						
1	3	-0.002	-0.002	-0.002	-0.002						
2	1	0.000	0.000	0.000	0.000						
2	2	0.002	0.002	0.002	0.002						
2	3	0.002	0.002	0.002	0.002						
3	1	0.004	0.004	0.004	0.005						
3	2	0.002	0.002	0.001	0.001						
3	3	0.000	0.000	0.000	0.000						
4	1	0.001	0.001	0.001	0.002						
4	2	0.000	0.000	0.000	0.000						
4	3	0.001	0.001	0.001	0.001						
5	1	0.000	0.000	0.000	0.000						
5	2	-0.001	0.000	0.000	0.000						
5	3	0.004	0.004	0.004	0.004						

Carbon stock changes in the soil pool are small (cf. Figure 6-5 and Table 6-23). The Yasso07 data are supported by measurements of the Swiss Soil Monitoring Network (see

Chapter 6.4.4). Carbon stock changes in litter are higher and more erratic than changes in the dead wood and soil pools (Figure 6-5). This is expected since non-woody material decomposes faster than dead wood (Tuomi et al. 2011) and there is a higher interannual variability in the production of foliage (Etzold et al. 2011). The carbon stock change in the dead wood pool is to a large extend driven by the increase in the dead wood volume following the hurricane Lothar (1999). As Lothar occurred between the NFI 2 (1993-1995) and NFI 3 (2004-2007), it strongly affects the results of the change analysis for dead wood volume in the period NFI 2 to NFI 3. Although the majority of the felled trees were removed, the dead wood volume increased significantly. As particularly the larger sized felled trees decay slowly (Didion et al. 2014a), the storm resulted in a sustained carbon sink. The additional dead wood pool which was created by the storm will slowly release the stored C over the coming decades. The trend of decreasing harvest rates starting after NFI3 further sustained the carbon sink of dead wood as more large-sized woody matter remains in the forest as trees that would be removed during harvest contribute to the dead wood pool. Large-scale disturbance events like Lothar that occur between two consecutive NFIs strongly affect the estimates of annually accumulating mass of carbon in dead wood that drives the Yasso07 simulation. This bias is expected to disappear following the switch to a continuous sampling approach in the NFI 4 (Brändli and Speich 2011).

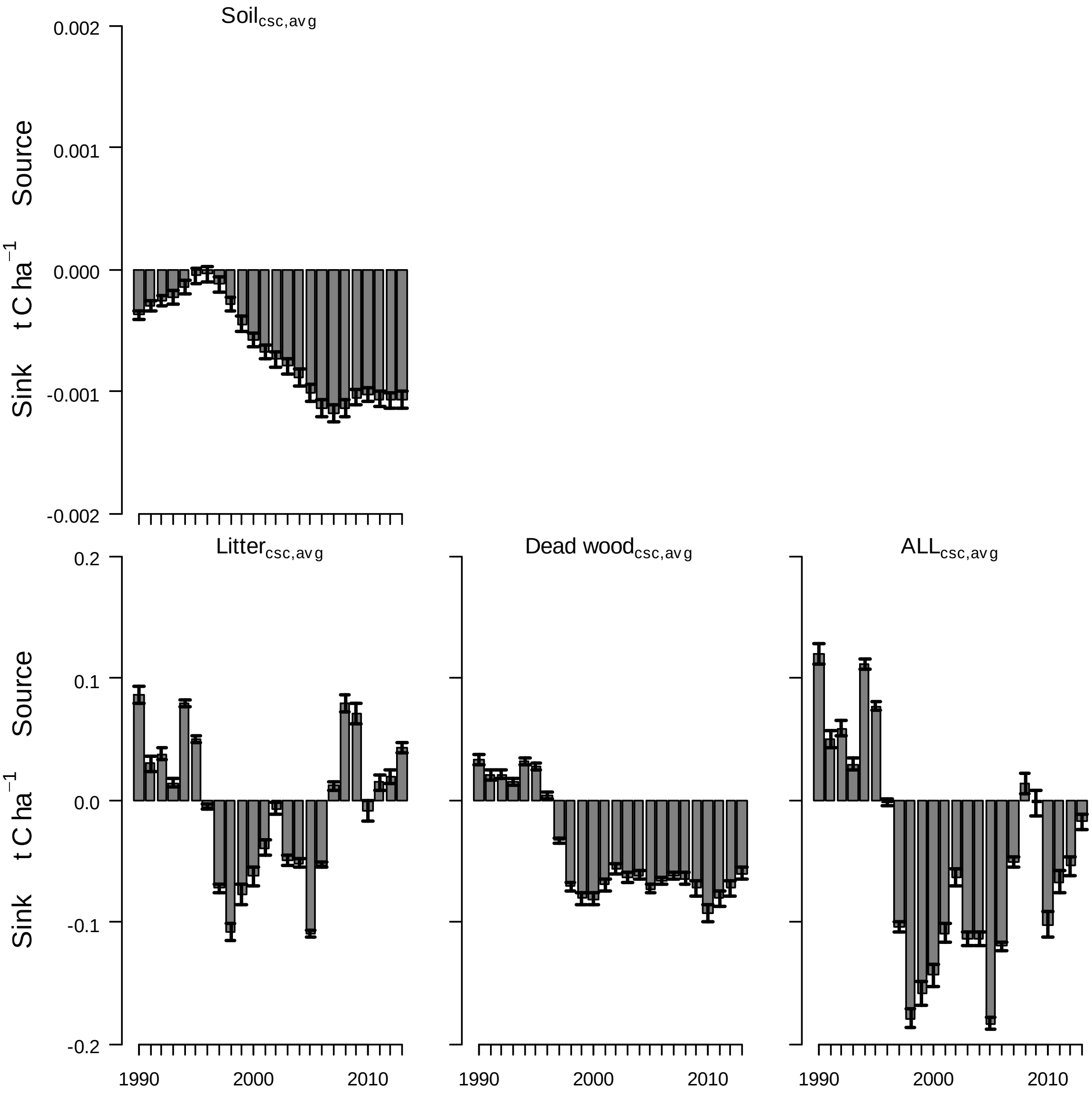


Figure 6-5 Mean carbon stock change (CSC) based on averaged (avg) annual carbon stocks for soil organic carbon, litter, dead wood and their sum (ALL). Note the different scale of the y-axis for $Soil_{csc,avg}$ in comparison to $Litter_{csc,avg}$, Dead $wood_{csc,avg}$ and $ALL_{csc,avg}$. Negative values indicate a sink of carbon, positive values a source of carbon.

6.4.2.9 Unproductive Forests (CC13): Stocks and Changes in Stocks of Living Biomass, Dead Wood, Litter and Soil Carbon

Unproductive forests consist of brush forests, inaccessible stands and unproductive forest not covered by NFI exhibit a high variability (see examples of unproductive forests in Switzerland in FOEN 2014f).

For transparency reasons, productive and unproductive forest areas are reported separately. However, there is only scarce information available about unproductive forests. In unproductive forests, wood is not harvested for economic reasons. Only in exceptional cases (e.g. wood log blocks a hiking trail) there can be an intervention where the log is moved, but not removed from the stand. Moreover, since yearly harvesting amounts from forest statistics

(FOEN 2014h) are distributed over the productive forests, total harvesting in Swiss forests is accounted for under CC12 remaining, thus all harvesting amounts are accounted for.

The national forest inventory does not incorporate unproductive stands CC13 in its regular inventory scheme because 1) the plots are difficult to access or it is not possible to carry out precise measurements (brush forests), (2) the plots are inaccessible or (3) the NFI forest definition is not fulfilled (forest not covered by the NFI).

- Brush forests: Since brush forests have no direct economic value in terms of wood harvest, an inventory of these stands has not been attributed high priority. During NFI 3, some plots in brush forests have been visited for the first time, but only a limited number of parameters like tree species, stem diameter and crown cover have been determined.
- Inaccessible stands: Inaccessible stands are forests which cannot be visited because of safety reasons (see description in Brändli 2010, p. 89). They are mainly located in the Alps and often grow on sites of low productivity: rocky sites, sites at high elevation near the tree line with a short vegetation period and low biological activity.
- Unproductive forests not covered by NFI: after the review of its first Initial Report (FOEN 2006h), Switzerland had to apply a forest definition for reporting activities under KP Art. 3.3 and Art. 3.4, which is different from the definition applied by the Swiss NFI and the Land Use Statistics AREA. The same definition is used for reporting under the UNFCCC and under the Kyoto Protocol. Because the country definition (NFI and AREA) was not in line with the specific requirements of the Kyoto Protocol forest definition, Switzerland had to develop an approach to classify certain AREA categories as forest. Those areas are not covered by the regular NFI and are situated in the threshold range between forests and alpine pastures with woody biomass of very low productivity. More specifically, it concerns the combination category “alpine pastures with cluster of trees” in Table 6-6 (LU=242 and LC 47).

Unproductive Forests (CC13): Carbon Stocks in Living Biomass

- Brush Forest: Brush forests in Switzerland mainly consist of *Alnus viridis*, horizontal *Pinus mugo var. prostrata* with a percentage cover of 65% and 16%, respectively (Tab. 1 in Düggelin and Abegg 2011). Following the NFI definition, brush forests are dominated by more than two thirds by shrubs. For brush forests, no NFI data are available to derive their growing stock since only a limited number of attributes are measured on these plots. Düggelin and Abegg (2011) analysed the carbon stock of total living biomass in Swiss brush forests and found an average value of 20.45 t C ha^{-1}.
- Inaccessible Stands: Inaccessible stands are considered similar to brush forest regarding biomass and carbon stock. Their area is determined based on land cover ‘tree vegetation’ in typically remote and high-elevation land uses such as avalanche chutes (land uses 403 and 422 in Table 6-6).
- Unproductive Forests not Covered by NFI: These forests are mainly associated with extensively pastured land where sparse tree vegatation (land cover 44 and 47 in Table 6-6) is found. As those forests are assumed to grow preferably on bad site conditions, an average growing stock (> 7 cm diameter) of 150 m^3 ha^{-1} is assumed. Multiplied by the mean BCEF of 0.69 (see Thürig and Herold 2013), an average biomass for these forests of 102.75 t ha^{-1} was estimated, which translates to 51.38 t C ha^{-1} (using the IPCC default carbon content of 50%).

The carbon content of unproductive forest was calculated as a weighted average of brush forest, inaccessible stands and unproductive forest not covered by NFI per spatial stratum:

[weighted C content]i = RSi * CS + (1- RSi) * CI

where RSi is the rate of the brush and inaccessible forest per spatial stratum i,

CS is the carbon content of brush and inaccessible forest (20.45 t C ha^{-1}),

CI is the carbon content of forest on unproductive areas (51.38 t C ha^{-1}).

Table 6-24 shows the carbon content per spatial stratum in t C ha^{-1}.

Table 6-24 Area of brush forest, inacessesibble forest and forest not covered by NFI, their areal fractions and the resulting weighted carbon content in t C ha^{-1} of Swiss unproductive forests (CC13) specified for all spatial strata. The respective areas of brush forest, inacessesibble forest and forest not covered by NFI were determined based on AREA data where brush forest corresponds to land use forest 3xx classified as CC13, inaccessible stands to land uses 403 and 422 classified as CC13, and forest not covered by NFI to land use 242 classified as CC13 (see Table 6-6).

NFI region	Altitude [m]	Brush forest [ha]	Inacessessible forest [ha]	Forest not covered by NFI [ha]	Fraction of brush and inaccessible forest	Fraction of forest not covered by NFI	Carbon stock in living biomass ($stockC_{l,i,13}$) [t C ha^{-1}]
1	<601	49	0	69	0.42	0.58	38.53
	601-1200	44	0	4'841	0.01	0.99	51.10
	>1200	6	0	4'648	0.00	1.00	51.34
2	<601	188	0	0	1.00	0.00	20.45
	601-1200	94	0	93	0.50	0.50	35.83
	>1200	1	0	633	0.00	1.00	51.33
3	<601	11	0	0	1.00	0.00	20.45
	601-1200	172	0	1'210	0.12	0.88	47.53
	>1200	3'486	5	8'482	0.29	0.71	42.36
4	<601	26	0	1	0.96	0.04	21.60
	601-1200	1'058	5	589	0.64	0.36	31.48
	>1200	42'795	50	18'808	0.69	0.31	29.88
5	<601	243	1	3	0.99	0.01	20.83
	601-1200	2'249	0	275	0.89	0.11	23.82
	>1200	17'776	7	2'568	0.87	0.13	24.35

Unproductive Forests (CC13): Carbon Stocks in Litter, Soil and Dead Wood

As stated previously, CC13 consists of very different forests and data are hardly available. Carbon stocks in litter and mineral soil under unproductive forests reveal therefore a very high spatial heterogeneity. Data on carbon stocks of litter and soil are not available. Carbon stocks of soil carbon and litter are assumed to be the same as for productive forests CC12, which are derived from Nussbaum et al. (2012, 2014).

So far, there are no data available for dead wood stocks in unproductive forests (CC13). Dead wood on CC13 forest stands is assumed to be zero.

Values for carbon stocks in litter, in soil and in dead wood for CC13 are listed in Table 6-4.

Unproductive Forests (CC13): Changes in Carbon Stocks of Living Biomass

There are a few case studies on carbon stocks, but just like in neighbouring countries with forests in mountainous regions, there are no repeated forest inventory data available for these unproductive forests (also known as “mountain forest without harvest”).

As no harvesting is conducted in unproductive forests, gross growth and cut and mortality of unproductive forest are assumed to be in balance. This approach is confirmed by two studies in which basal area and crown cover is used as a proxy for the stock of living biomass. An increase in basal area or crown cover, respectively, is positively correlated with an increase in living biomass (e.g. Nowak and Crane 2002). Living biomass in brush forests is increasing during the stage of establishment: the stand develops from a stand with grasses, herbs and some shrubs towards a stand dominated by shrubs and with a denser crown cover. A decrease in crown cover in unproductive forests is observed when natural disturbances like avalanches or rock fall partially damage the stand.

- Huber and Thürig (2014) analysed the available data on diameters of the terrestrial inventory NFI3 and NFI4. The authors found that the number of trees has increased over this 6 years period. Since no allometric functions are available for these stands, it is not possible to calculate stocks from these data. The authors calculated an increase in the mean basal area from 4.59 m^2 ha^{-1} in 2006 to 5.47 m^2 ha^{-1} in 2012.
- Ginzler (2014) analysed the crown cover density of 135 aerial photographs between 2006 (NFI3) and 2011 (NFI4) and found no statistical change in crown cover density of well-established, existing brush forests. The terrestrial NFI data, however, showed a slight increase in the basal area of trees in brush forests.
- Huber and Frehner (2013) showed that the expansion of Green Alder in eastern Switzerland has doubled in the past 75 years. Especially in the Alps or at unproductive sites, brush forests are expanding as summer pastures are abandoned. At these sites, an increase in crown cover is observed which correlates with an increment in carbon stocks. A literature review by Huber and Frehner (2012; for an overview see FOEN 2014f) showed that Green Alder has in general a strong annual gross growth, not only in very young stands, and that stands of Green Alder can be very vital at an age of over 100 years.

Considering the observed dynamics in brush forests, it is concluded that living biomass in unproductive forests is not a net source of carbon. Thus, living biomass is reported to be in balance (conservative estimate, Tier 1 approach). In Table 6-4 and in the CRF-tables, this is transcribed into “gains ($gainC_{l,i,13}$) = losses ($lossC_{l,i,13}$) = 0”.

Unproductive Forests (CC13): Changes in Carbon Stocks of Litter, Mineral Soils, Dead Wood

There are no repeated measurements of carbon stocks in mineral soils, litter, and dead wood.

Above, transparent and verifiable information has been given that in Switzerland living biomass in brush forest is increasing. An increase in biomass leads to an increase in litter and dead wood production, which again can lead to an accumulation in soil carbon. Based on that, it is concluded that mineral soils, litter, and dead wood in uproductive forest are not a net source of carbon. Carbon changes in mineral soils, litter, and dead wood are conservatively reported to be zero (Tier 1 approach). This assumption is supported by the following arguments:

- The areas of CC13 occur on higher elevation where microbiological processes in soils are slow (Hagedorn et al. 2010; Davidson and Janssens 2006).
- Unproductive forests grow on poor or rocky sites with thin or no organic layer. Brush forest protect the soils; in particular, Alder brush is not even destroyed by avalanches, rock fall when rock size is small or medium (Huber and Frehner 2014). By stabilizing soils, brush forests act as a perfect protection against soil erosion (Richard 1995; Stangle 2004).
- Green Alder has an ameliorative effect on the soil by fixing nitrogen with its nitrogen-fixing root nodules (Huber and Frehner 2014). Amelioration of soils enables an increase in biomass production which on the other hand increases the amount of litter and dead wood and finally leads to accumulation of soil carbon.
- No active logging occurs on unproductive stands and consequently, there is no human impact on the soils, litter and dead wood.

By providing this transparent and verifiable information (survey of peer-reviewed literature and reasoning based on sound knowledge of likely system responses), the requirements for application of Tier 1 are fulfilled.

For conversions within forest land (CC13 to CC12 and CC12 to CC13), no changes in carbon stocks of litter and soil carbon of mineral soils are calculated because carbon stocks of litter and soil carbon are equal for CC12 and CC13. The reason why these stocks are assumed to be equal is (1) because data are not available (see above) and (2) because it leads to a conservative estimate of changes in these pools. With the exception of brush forests, it is very likely that carbon stocks of litter and soil carbon are smaller under unproductive forests CC13 than under productive forests CC12. As the area changing from CC13 to CC12 is larger than from CC12 to CC13 (see Table 6-9), applying the stock-difference method (see Table Table 6-7) with equal stocks for litter and soil carbon under CC12 and CC13 is a conservative estimate.

Thus, a conservative estimate (Tier 1; no changes) is applied for all pools of unproductive forests.

6.4.2.10 Afforestations (CC11)

Living Biomass: Growing Stock and Changes in Growing Stock

The average growing stock and growth of afforestations were empirically assessed from NFI 1 and NFI 2 data, specifically with those stands that were approximately 10 years old in the first NFI and 20 years old in the second NFI. The average growing stock of those 20 year old stands was derived from NFI 2. The NFI data were stratified by altitudinal level. The growing stock of forest stands below 600 m was on average 90 m^3 ha^{-1}. The growing stock on sites between 600 and 1200 m was assumed to be one-third smaller (60 m^3 ha^{-1}) than on sites below 600 m, and two-thirds smaller on sites above 1200 m (30 m^3 ha^{-1}). As trees below 12 cm diameter at breast height (DBH) were not measured in the NFI, the growing stock of 10 year old stands below 600 m was assumed to be 2 m^3 ha^{-1}.

Within the first few years of stand age, the growing stock was assumed to develop exponentially. The development of the growing stock between 10 and 20 years on sites below 600 m was simulated by calibrating a logistical growth function. To simulate the development of growing stock on sites above 600 m, growing stock was assumed to develop one-third slower on sites between 600 and 1200 m, and two-thirds slower on sites above 1200 m. The annual growth was calculated as the difference between growing stocks of two following years. These assumptions are not valid for single stands, but can be applied as a rough simplification. Table 6-25 shows the simulated growing stock and growth for the three altitudinal levels.

Table 6-25 Estimated average growing stock and annual growth of forest stands in stem-wood over bark including stock up to 20 years (CC11) specified per altitudinal zone. Bench marks derived from NFI 1 and NFI 2 in bold letters (see text above).

Stand age	**< 601 m altitude**		**601 - 1200 m altitude**		**> 1200 m altitude**	
	Growing stock	**Growth**	**Growing stock**	**Growth**	**Growing stock**	**Growth**
[yr]	**[m^3 ha^{-1}]**	**[m^3 ha^{-1} $year^{-1}$]**	**[m^3 ha^{-1}]**	**[m^3 ha^{-1} $year^{-1}$]**	**[m^3 ha^{-1}]**	**[m^3 ha^{-1} $year^{-1}$]**
0-9	0	0	0	0	0	0
10	2	2	0	0	0	0
11	7	5	0	0	0	0
12	13	6	1	1	0	0
13	19	6	5	4	0	0
14	27	8	10	5	0	0
15	35	8	16	6	1	1
16	44	9	23	7	5	4
17	54	10	31	8	10	5
18	66	12	40	9	16	6
19	78	12	50	10	23	7
20	**90**	12	**60**	10	**30**	7

To convert the estimated growing stock (m^3 ha^{-1}) and growth (m^3 ha^{-1} $year^{-1}$), both expressed in volume units, into tonnes of carbon, the following equations were applied:

Carbon stock in living biomass = Average growing stock * BCEF * C content

Growth of living biomass = Average growth * BCEF * C content

Where

- C content: Carbon to total biomass ratio. The IPCC default of 50% was applied (IPCC 2006; Table 4.3)
- BCEF: Biomass conversion and expansion factor converting the volume of growing stock and the volume of net annual increment to total tree biomass and total tree biomass growth, respectively; an average value for coniferous and deciduous trees is taken from Thürig and Herold (2013).

Table 6-26 Carbon stock in living biomass (stem-wood over bark including stock without branches) and gain of living biomass (growth) in afforestations (CC11) specified per altitudinal zone. BCEF taken from Thürig and Herold (2013). Data for carbon stock in living biomass and gain of living biomass are displayed in Table 6-4.

Altitude [m]	Average stock of living biomass [m^3 ha^{-1}]	Average gain of living biomass [m^3 ha^{-1} yr^{-1}]	BCEF	Carbon content	Carbon stock of living biomass ($stockC_{l,i,11}$) [t C ha^{-1}]	Gain of living biomass ($gainC_{l,i,11}$) [t C ha^{-1} yr^{-1}]
<601	21.7	4.5	0.72	0.5	7.84	1.63
601-1200	11.8	3	0.73	0.5	4.3	1.09
>1200	4.25	1.5	0.76	0.5	1.61	0.57

Litter and Dead Wood (DOM): Carbon Stock and Carbon Stock Changes

In Switzerland, afforestations (CC11) occur mostly on grasslands and settlements (see Table 6-9) where there is no litter and no dead wood (Table 6-4). On afforestations, carbon stock in litter and dead wood is conservatively assumed to be zero (IPCC 2006, Chapter 4.3.2; see also Chapter 11.3.1.2 for details). Applying the stock-difference calculation approach (Table 6-3), calculated changes in the litter and dead wood pool after a afforestation are zero.

Soil: Carbon Stock and Carbon Stock Changes

The estimates for soil carbon stocks from Nussbaum et al. (2012, 2014) are used for afforestations (CC11; see Table 6-4 and Table 6-21). Carbon stock changes are calculated with the stock-difference method (see Table 6-3).

6.4.2.11 Organic Soils

Organic Soils - Carbon Stock

No specific information is available related to carbon stocks in organic soils under forest land. Therefore, the value calculated for cropland and permanent grassland based on Leifeld et al. (2003, 2005) is adopted for forest land, including CC11, CC12 and CC13. The approach uses measured carbon stocks in Swiss organic soils. The mean soil organic carbon stock (0-30 cm) for organic soils is 240 ± 48 t C ha^{-1}.

Organic Soils - Changes in Carbon Stocks due to Drainage

Drainage of forests is not a permitted practice in Switzerland (Swiss Confederation 1991). There are no nation-wide survey data available. It is possible that parts of the Swiss forest have been drained before 1990 or have been established on drained areas. All organic forest soils are conservatively reported to be drained (which is definitely an overestimation).

In order to calculate CO_2 emissions due to drainage, the default emission factor of 2.6 t C ha^{-1} yr^{-1} was applied according to the Wetland Supplement (IPCC 2014a, Table 2.1) for all forest stands (cf. Table 6-4).

6.4.2.12 N_2O Emissions from Forest Land

Fertilization of forests is prohibited by the Swiss forest law and adherent ordinances (Swiss Confederation 1991, 1992). Additionally, the “Ordinance on Chemical Risk Reduction“ (Swiss Confederation 2005) prohibits the application of fertilizers, including liming, in forests. A previous legal document prohibiting the use of fertilizers is the Law on Forests (cf. Art. 18 in Swiss Confederation 1991): “No use must be made in the forest of environmentally hazardous substances” with a direct reference to the Federal Act on the Protection of the Environment (Swiss Confederation 1983). Details of the Law on Forest Art. 18 are regulated in the Ordinance on Forests (Art. 27 in Swiss Confederation 1992). Hence, the application of fertilizers, including liming in forests has been prohibited since 1991 in Switzerland. Besides that, those management practices have never been common practice in Swiss forestry. It was therefore considered that this situation is valid since 1990. Therefore, no emissions are reported in CRF-table 4(I)A.

N_2O emissions from drainage of organic soils was calculated for forest land with an emission factor of 2.8 kg N_2O-N ha^{-1} and reported in CRF-table 4(II)A. This is the default value given in the Wetlands Supplement (IPCC 2014a, Table 2.5) for temperate forest land.

The calculation of emissons for categories 4(III) and 4(IV) (N_2O from Nitrogen Mineralization in mineral soils) is described in Chapter 6.10.

6.4.2.13 Emissions from Wildfires

Data on wildfires affecting Swiss forest land are obtained from cantonal authorities and are compiled by FOEN (FOEN 2014h). Table 6-27 shows the annual number of fires and the burnt area from 1990 to 2013.

As controlled burning is not allowed in Switzerland all fires are assigned to “wildfires”. The number and area of the fires are assigned to productive forests. This is a conservative estimate, since the "available fuel" of productive forests is higher than the carbon stocks of afforestations and unproductive forests. Moreover, this approach reflects reality quite well, since fires on afforestations or in unproductive forests are rather unlikely to occur for the following reasons:

- Non-FL to FL / afforestations and unproductive forest: the available fuel is small - there is very little dead woody material on the surface which can catch fire (Zumbrunnen et al. 2012);
- Unproductive forests: the available fuel is small since tree cover is not very dense (Zumbrunnen et al. 2012); moreover, in remote areas the cause of fire is restricted to flash of lightning.

Using the default emission factor of 7.10 g (kg combusted biomass)$^{-1}$, an emission factor for CH_4 of 0.903 Mg CH_4 ha^{-1} is cacluated (IPCC 2003, equation 3.2.20 and table 3A.1.16).

For N_2O, the default emission factor of 0.11 g (kg combusted biomass)$^{-1}$ is applied (IPCC 2003, Table 3A.1.16).

The mass of available fuel considered for calculating the emissions, depends on the greenhouse gas reported:

(1) For reporting CH_4 and N_2O emissions from wildfires, the mass of available fuel encompasses carbon stock of living biomass, litter and dead wood.

(2) For reporting CO_2 emissions from wildfires, the mass of available fuel encompasses carbon stock of litter. Losses in living biomass and dead wood due to wildfires are already reflected in the NFI dataset and included in CRF-table 4A. Yearly values of these losses are included in the data shown in Table 6-19 under “loss of living biomass" and in Table 6-23 under "net change in dead wood", respectively.

On average, the amount of living biomass amounts to 119.40 t C ha^{-1}or 238.81 t biomass ha^{-1}. This value has been derived from the mean growing stock in NFI 1, NFI 2, NFI 3 and NFI 4b (Brassel and Brändli 1999, Brändli 2010, Abegg et al. 2014).

On average in Swiss forests, the amount of litter amounts to 16.73 t C ha^{-1} or 33.40 t biomass ha^{-1} (Nussbaum et al. 2012, 2014). The amount of dead wood amounts on average to 5.23 t C ha^{-1} or 10.46 t biomass ha^{-1}. These values are derived from Table 6-21 as area-weighted averages over all spatial strata.

The fraction of the biomass combusted is 0.45 (IPCC 2003, Table 3A.1.12). Inserting these values in equation 3.2.20 of IPCC (2003), the emissions shown in Table 6-27 are calculated.

CH_4 and and N_2O emissions caused by wildfires are reported in CRF-table 4(V). CO_2 emissions caused by wildfires are included in CRF-table 4A (as described above) and 4(V). In Table 4(V), the emissions from all forest fires are reported under 4(V)A1, because it is not known which fires occur on forest land remaining forest land and which on land converted to forest land. Consequently, 4(V)A2 has the notation key "IE".

Table 6-27 Productive forest land affected by wildfires (FOEN 2014h) and resulting GHG emissions 1990-2013.

Year	Number	Area burnt [ha]	CH_4 [t]	N_2O [t]	CO_2 [t]
1990	216	1102	995.24	15.42	25'358.04
1991	157	148	133.66	2.07	3'405.62
1992	111	52	46.96	0.73	1'196.57
1993	99	42	37.93	0.59	966.46
1994	52	293	264.62	4.10	6'742.20
1995	56	438	395.57	6.13	10'078.79
1996	61	233	210.43	3.26	5'361.55
1997	77	1511	1364.62	21.14	34'769.52
1998	88	249	224.88	3.48	5'729.72
1999	31	9	8.13	0.13	207.10
2000	41	36	32.51	0.50	828.39
2001	39	37	33.42	0.52	851.40
2002	75	410	370.28	5.74	9'434.48
2003	189	564	509.36	7.89	12'978.16
2004	46	20	18.06	0.28	460.22
2005	97	47	42.45	0.66	1'081.51
2006	70	101	91.22	1.41	2'324.10
2007	64	234	211.33	3.27	5'384.56
2008	47	53	47.87	0.74	1'219.58
2009	52	42	37.93	0.59	966.46
2010	59	25	22.58	0.35	575.27
2011	77	167	150.82	2.34	3'842.83
2012	56	22	19.87	0.31	506.24
2013	54	24	21.40	0.33	545.36

6.4.2.14 NMVOC Emissions

Estimates for annual biogenic emissions of NMVOC in Switzerland for forests (and natural grassland) are available in SAEFL (1996a): The values are 92.0 kt for coniferous forests, 2.4 kt for deciduous forests and 0.61 kt for forest fires. These numbers are based on a study from Andreani-Aksoyoglu and Keller (1995). Approximately 97% of the total emissions are monoterpene and the rest consists of isoprene (Keller et al. 1995).

6.4.3 Uncertainties and Time-Series Consistency

Uncertainties

For living biomass, the following information on uncertainty related to the conditions in 2013 was used:

- Stem wood of growth (gains of living biomass) and cut & mortality (C&M; loss of living biomass) in NFI 4b and differences NFI 3-4b:

mean growth 8.95 m^3 ha^{-1} $year^{-1}$, mean C&M -7.64 m^3 ha^{-1} $year^{-1}$, resulting mean net change in stem volume 1.31 m^3 ha^{-1} $year^{-1}$

relative uncertainty: 2% for growth and 4% for C&M (Abegg et al. 2014)

resulting relative uncertainty of mean net change in volume: 27% (for calculation see Thürig et al. 2015)

- Carbon content in solid wood: 5-10% (background: Lamlom and Savidge 2003, assessment of carbon content in wood; Monni et al. 2007, 2%)
- Wood density: expert guess 10-20% (background: Lamlom and Savidge 2003)
- Biomass expansion function (for the Swiss GHG inventory, allometric functions for individual trees are applied): The uncertainty is estimated to be 30% (Monni et al. 2007, Appendix 1, 2.7-21.3%; Vanninen and Mäkelä 1999; Cronan 2003; Helmisaari and Hallbäcken 1998).

Thus, the total uncertainty of net carbon stock change in living biomass ($U_{liv.biom}$) in terms of carbon per unit area can be calculated as:

- addition of relative uncertainties to derive uncertainty for gains and losses following equation 3.1 in chapter 'Quantifying Uncertainties' (volume 1 of IPCC 2006)

  $U_{liv.biom} = (27^2 + 10^2 + 15^2 + 30^2)^{0.5} = 44.2\%$
- calculation of the absolute uncertainty, based on the mean gain of 0.53 t C ha^{-1} yr^{-1}:

  $U_{liv.biom}$ = 0.24 t C ha^{-1} yr^{-1}.

The uncertainty in the estimates of annual stock changes derived with the Yasso07 model originates from the following sources (see also Chapter 2.2.3 in Didion et al. 2014):

- spatial interpolation of the gridded climate data prepared by the Federal Office of Meteorology and Climatology MeteoSwiss (MeteoSwiss 2012a, b);
- C input estimates obtained from the NFI (measurement errors, allometries, etc.);
- decomposition parameters used in the Yasso07 model.

No data are available yet to estimate the uncertainty associated with the spatially interpolated temperature and precipitation data. MeteoSwiss is currently developing ensembles of the gridded climate data that will allow to quantify the effect of this source of uncertainty on the annual carbon stocks; the ensembles are expected to become available in 2016.

The uncertainty associated with carbon inputs (dead wood production and litterfall) was estimated based on estimates of uncertainty in a) litter turnover rates (Wutzler and Mund 2007), b) wood densities of deadwood in different decay stages (Dobbertin and Jüngling 2009), and c) spatial uncertainty in the NFI data approximated based on the estimation error for tree volume reported for the NFI (see Chapter 1.4 in Brändli 2010). Based on the mean carbon inputs and the estimated uncertainty, a distribution of possible values was obtained. Finally, the combined uncertainty from these sources was calculated. The uncertainty in the Yasso07 parameters was estimated based on a Markov Chain Monte Carlo approach (see also Tuomi et al. 2011). A distribution of possible parameter values was provided by A. Lehtonen, Finnish Forest Research Institute METLA. The uncertainty of Yasso07 estimates on carbon stocks and carbon stock changes in different pools, resulting from the uncertainty of carbon inputs and of model parameters, was obtained through Monte Carlo simulations: 10 values for carbon inputs and 10 parameter combinations were selected randomly and the combined uncertainty in Yasso07 estimates of carbon stocks and carbon stock changes in the soil, litter, and dead wood pools was calculated as (described in Didion et al. 2014).

Based on this approach the absolute uncertainty of the estimates of C stock changes arevalues based on Didion et al. 2014:

U_{Soil} = 0.000068, U_{Litter} = 0.004142 and $U_{Deadwood}$ = 0.005244t C ha^{-1} yr^{-1}.

Since the uncertainty associated with the climate data could not be included, the combined uncertainty in the carbon stock changes for deadwood, litter and soil was estimated conservatively.

The absolute uncertainty of the total carbon stock change is:

$$U_{tot} = (U_{liv.biom}^2 + U_{Soil}^2 + U_{Litter}^2 + U_{Deadwood}^2)^{0.5} = 0.24 \text{ t C ha}^{-1} \text{ yr}^{-1}.$$

The mean total carbon stock change in 2013 is the sum of the mean changes of living biomass, soil, litter and deadwood: 0.53 - 0.00 + 0.00 - 0.01 = 0.53 t C ha^{-1} yr^{-1}. Thus, the resulting relative uncertainty of the carbon stock changes for forest land is 45%.

Combined uncertainties of the activities under the Kyoto Protocol are shown in Table 11 8.

The emission factor uncertainty for wildfires is 70%. This is the default value given for non-CO_2 emissions in the Good Practice Guidance (IPCC 2003, section 3.2.1.4.2.4). It is used here also for the CO_2 emissions as the fraction of the biomass combusted is quite uncertain for temperate forests (IPCC 2003, Table 3A.1.12): mean=0.45, SD=0.16.

Uncertainties of activity data of category 4A Forest land are described in Chapter 6.3.3. . Table 6-5 lists the relative uncertainties in the LULUCF sector: an uncertainty of 45% was calculated for afforestations (4A2), 50% for Deforestations (4E2) and 45% for Forest Management (4A1).

Time-Series Consistency

Consistent time series of annual growing stocks were calculated backward or forward starting from the growing stock 2005, as derived from NFI 3 (see Chapter 6.4.2.6).

Consistent time series of dead wood, litter and soil carbon were calculated with the model Yasso07 (see Didion et al. 2014 and Chapter 6.4.2.8).

6.4.4 Category-Specific QA/QC and Verification

The general QA/QC measures are described in Chapter 1.2.3.

Estimation of Growing Stock, Gains and Losses of Living Biomass in productive forests

Biomass Conversion and Expansion Factors: For transparency reasons and for comparison with the Biomass Conversion and Expansion Factors (BCEFs) used in former submissions (FOEN 2012 and before), updated BCEFs were calculated and documented in FOEN (2013).

Afforestation CC11 – Growing stock and changes in growing stock

A comparison with neighbouring countries may provide indicative values. A direct comparison is, however, not possible because of different thresholds or stratifications used.The Austrian NFI (Umweltbundesamt 2012) reports an average (not stratified) volume for afforestations (age class 1-20 years) of 22 m^3 ha^{-1} which corresponds to approximately 6 t C ha^{-1}. This is within the range of the values reported in Switzerland's GHG inventory (see Table 6-26: 7.84 t C ha^{-1} for regions < 601 m and 1.61 t C ha^{-1} for regions > 1200 m). From this comparison, we conclude that the values reported in Switzerland's GHG inventory, which are based on both NFI data and expert judgment, reflect a realistic dimension for the category Afforestation (which is not a key category, see Chapter 11.6.1).

The Swiss estimates were also compared with literature values.

- Paul et al. (2009) found values of sink effects in the first decades after afforestation in the range of 1 to 30 t CO_2 ha^{-1} yr^{-1}. Based on data of the German forest inventory (*Bundeswaldinventur II*), the authors report a C sequestration rate of 2.8 t C ha^{-1} a^{-1} (10.3 t CO_2 ha^{-1} a^{-1}) in the first 20 years of an afforestation.
- The assumption of an exponential development of growing stock in the first few years is supported by Ryan et al. (2004). The authors also provide evidence for a differential development based on site-productivity with larger growth increments found on more productive sites.

Afforestation CC11 – Litter

In an experiment by Zimmermann and Hiltbrunner (2012; COST E639-project "Turnover and stabilization of soil organic matter: effect of land-use change in alpine regions"), litter accumulation in a 40 year old afforestation with Norway Spruce was determined. The authors found accumalation rates of 0.17-0.20 t C ha^{-1} yr^{-1}. Further relevant studies are discussed in Chapter 11.3.1.2.

Carbon Balance of two Mountain Forest Ecosystems in Switzerland: Net Ecosystem Exchange and Soil Respiration

Measurements of the net ecosystem exchange (NEE) and of soil respiration were conducted at a montane mixed forest over 5 years (Lägeren; 2005–2009; NFI production region 2), and at a subalpine coniferous forest over 12 years (Davos; 1997–2009; Swiss Plateau, NFI production region 4).

(1) Etzold et al. (2011) determined the net ecosystem exchange (NEE) by eddy covariance (EC) measurements. EC measurements, as well as biometric estimates indicate that both sites with two different mountain forest types were significant carbon sinks in the respective periods. During 2005 to 2009 NEE of the Lägeren forest ranged from -366 to -662 g C m^{-2} yr^{-1} (mean: -415 g C m^{-2} yr^{-1}), and of the Davos forest from -47 to -274 g C m^{-2} yr^{-1} (mean: -154 g C m-2 yr^{-1}).

(2) Rühr and Eugster (2009) measured soil respiration rates at these two Swiss forest sites. Modelled changes in soil carbon storage with the dynamic soil carbon model Yasso07 (see

also Didion et al. 2014) gave comparable results with measured soil respiration. The authors found that soils at the alpine site Davos acted as a significant carbon sink. Soils at the Lägeren site were neither a significant carbon sink nor a significant carbon source. This domestic study confirms the broadly spread knowledge that it is very difficult to detect short term changes in soil carbon stocks, since the uncertainty of the measurement is often higher than the actual change of the annual estimates (e.g. Falloon and Smith 2003).

Changes in Soil Carbon Stocks
Soil Organic Carbon (SOC) Dataset of the Swiss Soil Monitoring Network

The objective of the Swiss Soil Monitoring Network (http://www.nabo.admin.ch/?lang=en; NABO) is to assess soil quality in the long term and to validate appropriate soil protection measures. The network was established in 1985. Currently, it comprises 105 observation sites throughout Switzerland. For the statements below, the NABO sites had been classified according to the 18 LULUCF combination categories (CC). 28 sites of the network are located in forests (SAEFL 1993).

Repeated soil inventories at the soil monitoring sites are carried out every 5 years. Four replicate bulked soil samples from the upper soil layer 0-20 cm are taken at the monitoring sites (10m x 10m). For each bulked sample 25 single cores are taken at the site according to a stratified random sampling scheme. Further details can be found in SAEFL (2000a).

SOC of the archived soil samples was measured with a modified Walkley and Black method (ACW/ART 1998) in the same laboratory since 2006. Since 2012 we introduced in parallel the SOC analysis by a C/N- Analyser (ThruSpec, Leco company) and measured soil samples of almost all sites with both methods. Strong correlations between both methods were found, with slightly higher values measured by the C/N-Analyser as this analytical method provides total organic carbon (TOC). The resulting regression to transfer SOC-Walkley and Black measurements to TOC showed a high coefficient of determination of 97%. Therefore, we harmonized the dataset correcting the SOC values (Walkely and Black) to the measurements of the C/N-Analyser. For further SOC analysis of the 5th and 6th soil campaign we will only use the C/N-Analyser method. Thus, the SOC dataset (n = 1'884 measurements) presented here and in Chapters 6.4.4 and 6.5.4 is not subject to systematic methodological errors caused by different laboratories or methods. To assure the reliability and accuracy of the measurements, sampling quality, sampling preparation, chemical extraction, analysis and sample storage in the soil archive is evaluated. SOC measurements of a soil sample were repeated if a SOC value deviated more than a certain degree from the values of the other three bulked soil samples of the same sampling campaign.

The spatial variation of bulk density is included in calculating the carbon pools. Bulk density measurements and soil skeleton (> 2mm) were measured at the monitoring sites in the 4th (2000-04) and 5th (2005-09) re-sampling campaign (n=4 in each campaign per site), but not in the previous campaigns. As the mass of the fine earth (FE) is the relevant fraction for the element pools in the soil, the bulk density refers to the mass FE. The measured skeleton fraction of the volume sample is substracted before. The temporal changes of the top soil bulk density between the 4th and 5th campaign were quite small and they differ between -0.2 and 0.1 g/cm^3. We presumed that the bulk density of the first three sampling campaigns ranged within the values measured in the 4th and 5th re-sampling campaign, i.e. propagated the variability of the measurements through Latin Hypercube sampling (n = 1'000 simulation runs) assuming a normal distribution of the bulk density and SOC measurements for each site.

The SOC pools for the forest top soils (0-20 cm) ranged between 35.4 t C ha^{-1} (min) and 135.8 t C ha^{-1} (max) and were on average 70.6 t C ha^{-1}. In these numbers we exclude one coniferous forest site that revealed large SOC pools up to 191 t C ha^{-1}. Figure 6-6 shows that on average, SOC pools did not change monotonously during the measurement period between 1989 and 2009 in the sampled forest soils. At some of the forest monitoring sites higher values were found in the 3rd re-sampling campaign.

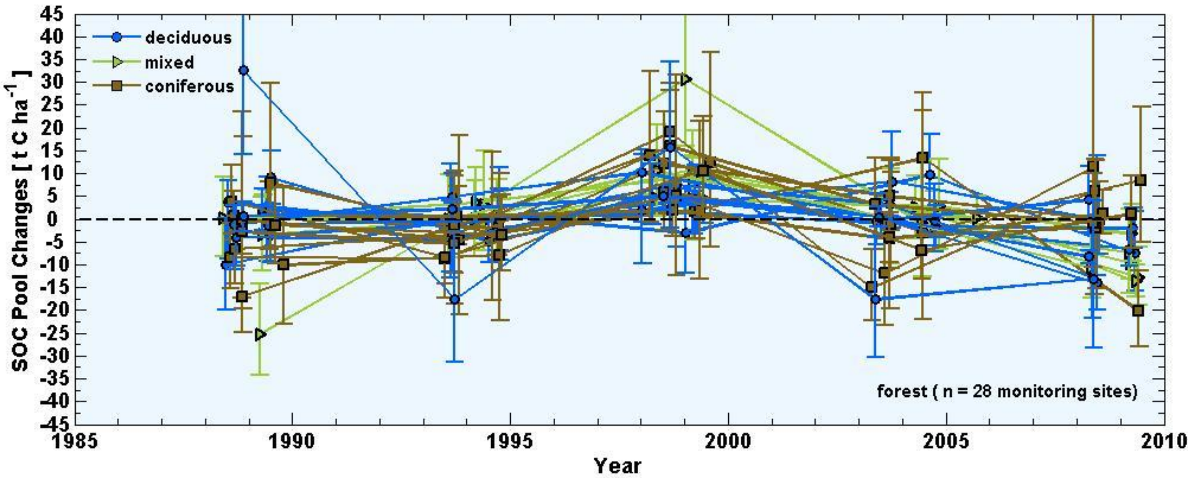


Figure 6-6 Time series of measured SOC pool changes in the top soil (0-20 cm) at the 28 NABO forest sites from the 1st to the 5th re-sampling campaigns. SOC pools were centred by the median SOC pool of all re-samplings of the monitoring site. Each pool value presents the median of four bulked soil samples per campaign with measured SOC and bulk density. The error bars indicate the 25% and 75% percentiles resulting from the spatial variation of the sites and the errors along the measurement chain. The altitude of the forest sites ranges between 380 and 1690 m a.s.l.

Detailed studies at monitoring sites showed that short-term temporal variation of soil properties can result from different site conditions at the sampling date, e.g. regarding soil moisture, soil temperature and bulk density (Keller et al. 2006). For instance, at two forest sites six re-samplings within three years revealed short-term variation of the SOC content between ± 1.8 % and ± 0.6 %. Therefore, the majority of the measured temporal variation for all forest sites is interpreted as natural variation (noise) and not as real SOC changes (signal). This hypotheses is also supported by the fact that the soil samples in the 3rd resampling campaign were taken earlier in spring time as in the other sampling campaigns and hence, soil moisture content of the samples was higher on average. This might explain the large temporal variation, in particular at coniferous forest sites with a pronounced organic layer. Using a robust linear regression approach for the SOC pool data of the forest soils, the 95% confidence interval for the SOC pool was ± 1.5 t C ha^{-1}. In order to capture as good as possible the natural variation of these site-specific characteristics, standard operation procedures and quality assurance were implemented since the 4th soil campaign. Further work will focus on the correction of the measured C pools to equivalent mass of the fine earth < 2 mm. In this way, we presume that the 95% confidence interval of the mean SOC pool can be reduced to some degree.

In comparison, the mean change in SOC which was obtained with Yasso07 for the period 1990-2010 was -0.0006 ±0.000275 t C ha^{-1} yr^{-1} (based on data in Didion et al. 2014). This value would correspond to -0.012 t C ha^{-1} for the monitoring period of the NABO network (20 years). The analysis strongly suggests that modelled SOC pool changes are not inconsistent with the repeated soil inventories in the NABO network. As indicated by the 95% confidence interval for the 28 forest monitoring sites, the noise is two orders of magnitude higher than the modelled signal.

Uncertainty Estimates

The uncertainty reported by Finland, where the Yasso07 model is also applied, was 46.8% for the 2012 emission factor in South Finland, 26.2% in North Finland, and 24.1% for the net change in the whole country (Statistics Finland 2014: Chapter 7.2.4.2).

6.4.5 Category-Specific Recalculations

For this submission, most recent NFI data (NFI 4b, covering the period 2009-2013) were applied for productive forests (CC12) (Thürig et al. 2015; see Chapter 6.4.2.1).

The accuracy of the estimates of carbon stocks and carbon stock changes was improved by eliminating errors in the derivation of litter and dead wood inputs (see Chapter 2.3 in Didion et al. 2014) which were due to the change from an interval-based inventory to a continuous inventory.

Updated estimates of yearly changes in carbon stocks of soil organic carbon, dead wood and litter, modelled with Yasso07, are described in Didion et al. (2014). The revision had a negligible impact on the estimates of carbon stock changes in the litter and soil carbon pools. The largest effect occurred in the dead wood pool since 2006. The period since 2006 was previously estimated as a source, whereas now it is a small sink. The national estimate for mean carbon stock changes in dead wood (CWD) 2011-2012 reported in the previous GHG inventory was a source of 0.220 ±0.005 Mg C ha^{-1} (FOEN 2014) compared to a sink of -0.072 ±0.006 Mg C ha^{-1} calculated for the same period based on the improved methodology.

Carbon stocks of unproductive forests have been updated using the study of Düggelin and Abegg (2011) and revision of the area based on AREA rather than NFI data (see Chapter 6.4.2.9).

N_2O emissions from drained organic soils are reported for the first time on forest land (in category 4(II)).

The emission factor for organic soils on forest land was changed from -0.68 to -2.6 t C ha^{-1} yr^{-1}, i.e. the new default emission factor for temperate drained forest according to the Wetland Supplement (IPCC 2014a, Table 2.1).

6.4.6 Category-Specific Planned Improvements

A research project running at the Swiss Federal Institute for Forest, Snow and Landscape Research WSL focuses on the growing stock of sites which were converted from non-forest land to forest land (used as a proxy for afforestations).

Background information for the calculation of carbon stocks in organic soils under forests will be available from an ongoing study at Agroscope. Potential revisions of carbon stocks in organic soils under forests could be incorporated in a future submission.

An ongoing study at Agroscope measured soil carbon stocks in organic soils under forests of three different vegetation units. These data will help to assess applied emission factors for organic soils.

Further research is underway to estimate yearly values for gross growth. First results of a study investigating the relationship between climate and gross growth (Thürig et al. 2009) are expected in the course of 2015.

The parameterization and application of the model Yasso07 to get better estimates of temporal changes in soil carbon, LFH layer and dead wood will be further improved. New parameters are expected to be released in 2015 by the model developers at Finnish Environment Institute and Tampere University of Technology (http://www.syke.fi/en-US/Research__Development/Research_and_development_projects/Projects/Soil_carbon_model_Yasso/News). Improvements to the application of Yasso07 in Switzerland are foreseen at the earliest for the GHG inventory 1990-2015 (to be submitted in 2017) with regards to a) the evaluation of the uncertainty associated with the spatial interpolation of the climate data, and b) the contribution of fine woody litter and of shrubs to the non-woody litter inputs.

Projects in a new national research programme (Sustainable Use of Soil as a Resource: "SOM control", http://www.nfp68.ch/E) aims at identifying the drivers of soil organic matter storage in Swiss forest soils. The objectives are to assess how forest productivity and tree species composition affect soil organic matter storage, to investigate if and how land-use history affects carbon pools in soils, to estimate the influence of climate, temperature and precipitation on soil organic matter stocks, to link soil organic matter stocks to physico-chemical parameters controlling soil organic matter stabilization and to model soil organic matter and evaluate the residuals to measured soil organic matter stocks. In the long term, results from these studies are expected to improve the reporting of emissions by sources and removals by sinks in category 4A.

6.5 Category 4B – Cropland

6.5.1 Description

Approach 1 Key category 4B1

CO_2 from Cropland remaining Cropland (level and trend).

Approach 2 Key category 4B1

CO_2 from Cropland remaining Cropland (level and trend).

The category 4B2 Land converted to Cropland is not a key category.

Swiss croplands belong to the cold temperate wet climatic zone. Carbon stocks in aboveground living biomass and carbon stocks in mineral and organic soils are considered. Croplands (CC21) include annual crops and leys in arable rotations (see Table 6-2 and Table 6-6). Because arable cropping mainly occurs in the temperate Swiss Central Plateau and no elevation-dependent soil carbon stocks are available for Swiss croplands (Leifeld et al. 2005), no stratification of carbon stocks has been applied.

In 2013, 4B1 Cropland remaining Cropland was a net source of 842 kt CO_2 due to (I) a decrease in living biomass between 2012 and 2013 and due to (II) emissions from organic soils. Average living biomass was increasing slightly over the period 1990-2013. However, annual fluctutations in net carbon stock changes of biomass are considerable (see Table 6-29). Since carbon stocks on mineral soils are assumed to be in balance (i.e. no carbon stock changes occur on mineral soils) all soil emissions in 4B1 were generated by carbon mineralization in organic soils, mainly in the lowest altitudinal zone (z1: 98%). Overall, organic soils account for 2.7% of cropland area in Switzerland.

4B2 Land converted to Cropland was a small net source of 24 kt CO_2 in 2013.

6.5.2 Methodological Issues

6.5.2.1 Carbon in Living Biomass

Annual biomass carbon stocks are shown in Table 6-28. They are calculated as area-weighted means of standing stocks at harvest for the seven most important annual crops (barley, wheat, maize, silage maize, sugar beet, fodder beet, potatoes) and as cumulated annual harvested biomass for leys.

The annual mean standing biomass carbon stock per hectare is calculated as:

Biomass cropland = Σf (Af / At) * Cf

where Af = Area of crop type f, At = total cropping area and Cf = yield (annual crops, leys) for the particular crop (t C ha^{-1}). Annual values for Af, At and Cf were published by the Swiss Farmers Union (SBV 2014).

The resulting mean biomass stock for Swiss cropland over the inventory time period is 4.70 ± 0.35 (1 SD) t C ha^{-1}.

Table 6-28 Annual values for arable crop yields (i.e. carbon stocks) and area-weighted mean (t C ha^{-1}) (SBV 2014), assuming a carbon fraction of 0.5 (IPCC default).

crop	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	CC21: yield [t C ha^{-1}]									
Barley	2.36	2.47	2.48	2.54	2.19	2.29	2.69	2.69	2.86	2.18
Wheat	2.36	2.54	2.35	2.53	2.34	2.56	2.84	2.55	2.63	2.24
Maize	3.51	3.42	3.53	3.78	3.72	3.55	3.64	3.94	3.87	3.78
Silage maize	7.37	6.59	7.15	6.72	6.11	6.03	4.98	7.08	6.88	6.49
Sugar beet	7.41	6.91	7.04	7.63	6.72	6.78	7.83	7.76	7.42	7.48
Fodder beet	6.70	6.51	6.64	6.77	5.66	5.49	6.41	6.53	6.06	5.79
Potatoes	4.47	4.39	4.65	4.83	3.65	3.88	5.36	5.05	4.44	3.87
Leys	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11
Mean	4.34	4.30	4.39	4.44	4.12	4.28	4.51	4.72	4.67	4.43

crop	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	CC21: yield [t C ha^{-1}]									
Barley	2.55	2.38	2.68	2.35	2.92	2.61	2.64	2.57	2.58	2.73
Wheat	2.53	2.35	2.42	2.16	2.62	2.46	2.49	2.57	2.58	2.60
Maize	4.10	3.80	3.92	1.83	4.09	4.10	3.30	4.32	4.12	4.42
Silage maize	6.68	6.45	4.93	5.96	6.52	8.23	7.01	8.02	8.09	7.60
Sugar beet	8.74	6.51	8.52	7.89	8.60	8.50	7.30	8.37	8.73	9.37
Fodder beet	6.71	5.75	5.95	5.67	6.13	6.15	6.25	6.21	6.30	6.72
Potatoes	4.67	4.13	4.30	3.71	4.34	4.26	3.60	4.59	4.71	5.12
Leys	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11
Mean	4.71	4.51	4.54	4.41	4.89	4.97	4.70	5.07	5.13	5.19

crop	2010	2011	2012	2013	mean 1990-2013
	CC21: yield [t C ha^{-1}]				
Barley	2.56	2.75	2.75	2.45	2.55
Wheat	2.48	2.72	2.49	2.32	2.49
Maize	3.61	4.13	3.85	3.12	3.73
Silage maize	7.47	8.42	8.06	7.64	6.94
Sugar beet	8.03	10.38	9.58	7.61	7.96
Fodder beet	6.49	6.65	5.58	4.67	6.16
Potatoes	4.26	5.04	4.52	3.40	4.39
Leys	6.11	6.11	6.11	6.11	6.11
Mean	4.99	5.44	5.23	4.90	4.70

6.5.2.2 Carbon in Soils

Soil carbon stocks in mineral soils under cropland are calculated based on Leifeld et al. (2003, 2005). The approach correlates measured soil organic carbon stocks (t ha^{-1}) for arable land and leys with soil texture after correction for soil depth and stone content. Area upscaling uses the Swiss digital soil map (SFSO 2000a), and average stocks are calculated as weighted means using the area of arable land and leys. The mean soil organic carbon stock (0-30 cm) for cropland is 53.40 ± 5 t C ha^{-1}.

It should be noted that current carbon stocks are not only the result of the conditions for productivity and carbon turnover under different land-use types, but are also determined by farmers' decisions to use a site in a specific way due to the demands of a crop or the suitability of a site, e.g. regarding machine use (see Leifeld et al. 2003: 65).

Soil carbon stocks in organic soils under cropland are calculated based on Leifeld et al. (2003, 2005). The approach uses measured carbon stocks in Swiss organic soils. The mean soil organic carbon stock (0-30 cm) for cultivated organic soils is 240 ± 48 t C ha^{-1}.

6.5.2.3 Changes in Carbon Stocks

Carbon stocks in living biomass intermittently increased from 4.34 t C ha^{-1} in 1990 to 4.90 t C ha^{-1} in 2013 (Table 6-28; SBV 2014). The difference in biomass stock between a specific year and the preceding year is reported as gain or loss of carbon (see Table 6-29). The resulting values are in the range between -0.33 and 0.49 t C ha^{-1} yr^{-1} with an average of 0.02 t C ha^{-1} yr^{-1} for the inventory time period. This average value is used for the year 1990 as there are no data for 1989.

Changes of carbon stocks in mineral soils are assumed to be zero for cropland remaining cropland.

The annual net carbon stock change in organic soils was estimated to -9.52 t C ha^{-1} according to measurements in Europe including Switzerland as compiled by Leifeld et al. (2003, 2005) and rechecked by ART (2009b).

In the case of land-use change, the net changes in biomass and soil are calculated as described in Chapter 6.1.3.

Table 6-29 Annual carbon data for living biomass for cropland (CC21), 1990-2013. Annual carbon stocks are broken down for arable crops in Table 6-28. Highlighted data for 1990 as displayed in Table 6-4.

Cropland	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
	CC21: carbon stock [t C ha^{-1}] and gain/loss in living biomass [t C ha^{-1} yr^{-1}]									
stock	4.34	4.30	4.39	4.44	4.11	4.28	4.51	4.72	4.67	4.43
gain	0.02	0.00	0.09	0.05	0.00	0.17	0.23	0.21	0.00	0.00
loss	0.00	-0.03	0.00	0.00	-0.32	0.00	0.00	0.00	-0.05	-0.24

Cropland	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
	CC21: carbon stock [t C ha^{-1}] and gain/loss in living biomass [t C ha^{-1} yr^{-1}]									
stock	4.71	4.51	4.54	4.41	4.89	4.97	4.70	5.07	5.13	5.19
gain	0.28	0.00	0.03	0.00	0.49	0.08	0.00	0.37	0.06	0.06
loss	0.00	-0.21	0.00	-0.13	0.00	0.00	-0.27	0.00	0.00	0.00

Cropland	**2010**	**2011**	**2012**	**2013**	**mean 1990-2013**
	CC21: carbon stock [t C ha^{-1}] and gain/loss in living biomass [t C ha^{-1} yr^{-1}]				
stock	4.99	5.44	5.23	4.90	4.70
gain	0.00	0.45	0.00	0.00	0.11
loss	-0.20	0.00	-0.21	-0.33	-0.09

6.5.2.4 N_2O Emissions from Cropland

N_2O emissions from drainage of organic soils on cropland are reported in the agriculture sector.

The calculation of emissons for categories 4III and 4IV (N_2O from Nitrogen Mineralization in mineral soils) is described in Chapter 6.10.

6.5.3 Uncertainties and Time-Series Consistency

A range of possible carbon stock changes in mineral soils has been determined by the Swiss Soil Monitoring Network (NABO). The upper and lower margin of the 95% confidence interval for carbon stock changes under cropland is 0 ± 0.52 t C ha^{-1} (Keller 2013). This absolute uncertainty is used to calculate relative uncertainties for 4B1 and 4B2 by dividing with the mean net emission per hectare of 4B1 and 4B2, respectively. In 2013, the mean net emissions were 0.593 t C ha^{-1} for 4B1 and 0.402 t C ha^{-1} for 4B2 (calculated from CRF-table 4B). The resulting relative uncertainties are 88% for 4B1 and 129% for 4B2, respectively (Table 6-5).

In the uncertainty analysis, these values were chosen for the overall emission factor uncertainties for CO_2 in sectors 4B1 and 4B2 as they dominate the other sources of uncertainty by far.

- Uncertainties for soil carbon stocks are given together with the mean value in the text above: 9% for mineral soils and 20% for cultivated organic soils. They take into account uncertainties in measured carbon contents and predicted soil bulk densities, i.e., they consider only uncertainties in emission factors.
- The relative uncertainty in yield determination has been estimated at 13% for biomass carbon from agricultural land (Leifeld and Fuhrer 2005). Data on biomass yields for different elevations and management intensities as published by FAL/RAC (2001) are based on many agricultural field experiments and have a high reliability.
- The uncertainty of the carbon stock change in organic soils is 23% as reported by Leifeld et al. (2003: 56).

Uncertainties of activity data of category 4B Cropland are described in Chapter 6.3.3.

Consistency: Time series for Cropland are all considered consistent; they are calculated based on consistent methods and homogenous databases.

6.5.4 Category-Specific QA/QC and Verification

The general QA/QC measures are described in Chapter 1.2.3.

Changes in Living Biomass

In 2012 an assessment of the appropriateness of the estimated pools of carbon in living biomass was conducted (ART 2012a). It came to the conclusion that almost all carbon stocks and carbon stock changes are in the expected range of the IPCC Guidelines and Good Practice Guidance. Nevertheless there is room for improvements. However, given the relatively low significance of the respective emissions a major effort in this area is hardly justified. Consequently, the biomass carbon pools will eventually be recalculated only in the course of the new planned Tier 3 approach for quantification of carbon stocks and carbon stock changes in agricultural soils (see Chapter 6.5.6).

Changes in SOC Pools

A SOC pool dataset provided by the Swiss Soil Monitoring Network (NABO; see Chapter 6.4.4) supports the Tier 1 assumption that changes of carbon stocks in mineral soils are zero for cropland remaining cropland (cf. UNFCCC 2011: §94). The SOC pool changes measured at 38 cropland monitoring sites in the Swiss Soil Monitoring Network show a slight trend towards decreasing SOC pools since 1985 (Figure 6-7). However, this trend is not statistical significant yet. The range of the calculated SOC pools is quite large (27.7 - 598 t C ha^{-1}), as three cropland soil monitoring sites are on peat soils. These three sites are excluded in Figure 6-7. Average SOC pool in the topsoils (0-20 cm) of the remaining 35 cropland monitoring sites for all soil sampling campaigns was 45.4 t C ha^{-1}. At the three cropland sites on peat soils the temporal variation of SOC content during the last 20 years ranged between ± 0.4%, corresponding to SOC pool changes larger than ± 10 t C ha^{-1}. However, for the majority of cropland sites the temporal variation found was smaller (± 0.2%), the confidence intervall of the SOC pool changes calculated by robust regression was ± 0.4 t C ha^{-1} over the last 20 years. This finding is in agreement with the detailed study mentioned in Chapter 6.4.4 (Keller et al. 2006), where six re-samplings of two cropland sites within three years revealed natural SOC content variation of ± 0.23% in the topsoil. The temporal variation of the SOC content and SOC pools at the cropland sites are rather small and possible future changes can be detected by this soil monitoring design.

Yet, the results suggest that Swiss cropland mineral soils did not act as a net carbon source or sink during the last 20 years. The results of the 6th soil campaign (2010-2014), that will be available in 2015 for the majority of the monitoring sites, will provide more evidence if the slight trend of decreasing SOC in cropland soils will be confirmed. In addition, SOC pools of the whole soil profile have to be determined as top soil SOC pools might be changed from changing land management practices such as the ploughing depth.

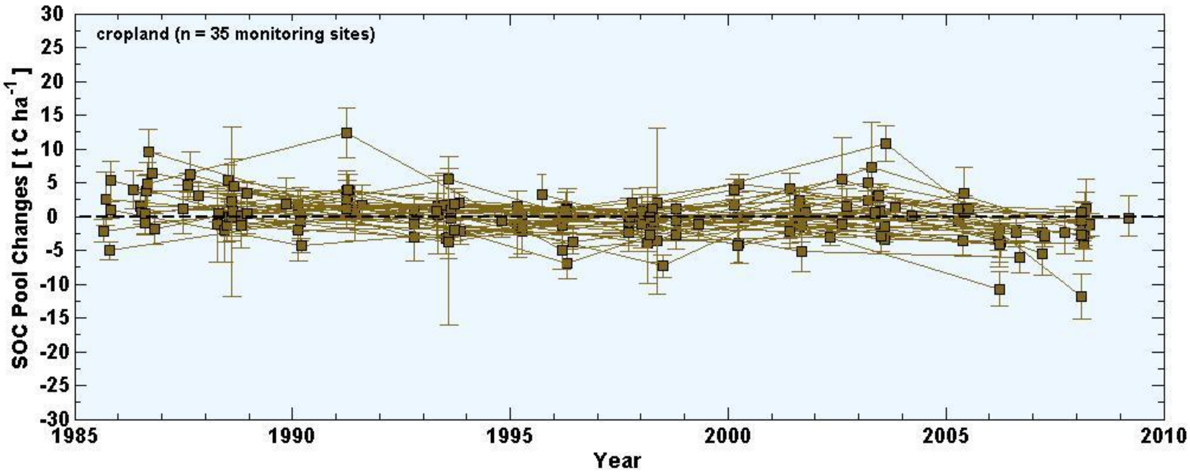


Figure 6-7 Time series of measured SOC pool changes in the top soil (0-20 cm) at 35 NABO cropland sites from the 1st to the 5th re-sampling campaigns. SOC pools were centred by the median SOC pool of all re-samplings of the monitoring site. Each pool value presents the median of four bulked soil samples per campaign with measured SOC and bulk density. The error bars indicate the 25% and 75% percentiles resulting from the spatial variation of the sites and the errors along the measurement chain. The altitude of the cropland sites ranges between 209 and 945 m a.s.l.

Short-term Land-Use Changes in Arable Rotations

Short-term land-use changes between "grassland" and cropland are to be expected for leys in arable rotations. However, leys are allocated to cropland by the Swiss Land Use Statistics (AREA) and are thus not considered grasslands in the common sense (i.e. permanent grassland). Furthermore, only long-term changes between cropland and grassland are considered relevant for carbon stock changes in soils. Since only long-term land-use changes are registered by the Swiss Land Use Statistics (AREA), carbon stock changes in soils associated with land-use changes between cropland and grassland and vice versa are adequately reported in the GHG inventory.

6.5.5 Category-Specific Recalculations

The provisional value of carbon stock in living biomass for the year 2012 was replaced by the definitive value. The carbons stock change in living biomass was recalculated for 1990 (it is the long-term average 1991-2013; cf. Table 6-30).

6.5.6 Category-Specific Planned Improvements

Information about carbon stock changes in soils for cropland remaining cropland will become available from Agroscope research activities. A pilot study to evaluate possible Tier 3 methodological approaches for quantification of carbon stocks and carbon stock changes in agricultural soils (cf. UNFCCC 2011: §94) has been terminated (Köck et al. 2013).

The Research Institute of Organic Agriculture FiBL in Frick (CH) runs a project with focus on the determination of sources and sinks of greenhouse gases in Swiss arable soils (project duration 2012-2014; co-funded by FOEN).

A new study on GHG emissions from peatlands and organic soils under different land use (Agroscope in collaboration with the University of Basel, 2013-2016, financed by FOEN) will improve the robustness of domestic emission factor estimates for soils rich in organic matter in the medium term.

Projects in a new national research programme ("Sustainable Use of Soil as a Resource", http://www.nfp68.ch/E) focus on (1) sustainable management of organic soils, (2) agricultural management and below ground carbon inputs, and (3) an integrated modelling framework to monitor and predict trends of agricultural management and their impact on soil functions at multiple scales. In the long term, results from these studies are expected to improve the reporting of emissions by sources and removals by sinks in category 4B.

6.6 Category 4C – Grassland

6.6.1 Description

Approach 1 Key category 4C2

CO_2 from Land converted to Grassland (trend).

Approach 2 Key category 4C1

CO_2 from Grassland remaining Grassland (level and trend).

Approach 2 Key category 4C2

CO_2 from Land converted to Grassland (level and trend)

Swiss grasslands belong to the cold temperate wet climatic zone.

Grasslands are subdivided into permanent grassland (CC31), shrub vegetation (CC32), vineyards, low-stem orchards (‘Niederstammobst’) and tree nurseries (CC33), copse (CC34), orchards (‘Hochstammobst’; CC35), stony grassland (CC36), and unproductive grassland (CC37), see Table 6-2 and Table 6-6. Carbon stocks in living biomass and carbon stocks in soils have been estimated for every subclass and have been considered accordingly in the calculation scheme.

In CRF-table 4C2, the land-use types CC32, CC33, CC34 and CC35 are merged under the notation ‘woody’ and CC36 and CC37 are merged under ‘unproductive’ (see Table 6-2).

In 2013, 4C1 Grassland remaining Grassland was a net source of 121 kt CO_2. Carbon stocks in mineral soils and carbon stocks in living biomass under constant land use are considered to be in balance (i.e. no carbon stock changes do occur). The highest contribution were thus generated by carbon mineralization in organic soils under permanent grasslands (195 kt CO_2), although only 0.47% of all grassland soils in Switzerland are organic soils. Contributions of other grassland source categories remaining grassland were of minor importance.

4C2 Land converted to Grassland was a net source of 159 kt CO_2 in 2013. The highest individual contribution came from 4C2.1 Forest Land converted to Grassland being responsible for a net source of 323 kt CO_2. Most of this source (67%) is due to net changes in living biomass from deforestation. Land-use change source categories 4C2.2 to 4C2.5 were net sinks due to sequestration of CO_2 in mineral soils and biomass in the course of the conversion to grassland.

6.6.2 Methodological Issues

6.6.2.1 Carbon in Living Biomass

Permanent Grassland (CC31)

Permanent grasslands range in altitude from < 300 m to 3000 m above sea level. Because both biomass productivity and soil carbon rely on the prevailing climatic and pedogenic conditions, grassland stocks were calculated separately for three altitude zones (corresponding to those used in category 4A Forest Land).

Standing stocks for permanent grasslands (t C ha^{-1}) are calculated as the annual cumulative yield of differentially managed grasslands (meadows, pastures, alpine pastures and meadows) based on FAL/RAC (2001; Table 6-30), assuming a carbon fraction of 0.5 (IPCC default). Mean standing above-ground biomass stocks were taken for each of the altitudinal zones because the spatial distribution of grassland management types is not known.

Table 6-30 Annual yields of differentially managed permanent grassland (CC31). Each value represents the mean of two fertilization levels.

Management	Altitude [m]	Annual yield [t C ha^{-1}]
Meadow	<601	5.88
	601-1200	4.38
	>1200	3.25
Pasture	<601	4.63
	601-1200	3.75
	>1200	2.75
Alpine pasture and meadow	601-1200	3.75
	>1200	0.75

Data for root biomass C was compiled by ART (2011a) based on published data of Swiss grassland. Carbon stocks in roots are in the range of 1.82 - 5.70 t C ha^{-1} depending on altitude. Root biomass is added to above-ground biomass to derive the total living biomass for CC31. Table 6-31 shows the living biomass of permanent grassland for the three altitudinal zones presented as the cumulated annual yield including roots.

Table 6-31 Root biomass Croot and total living biomass Cl of permanent grassland (CC31).

Altitude [m]	Croot [t C ha^{-1}]	Cl [t C ha^{-1}]
<601	1.82	7.08
601-1200	2.04	6.00
>1200	5.70	7.95

Shrub Vegetation (CC32) and Copse (CC34)

Due to the lack of more precise data, the living biomass of shrub vegetation and copse was assumed to be equal to the living biomass of brush forest as described in Chapter 6.4.2.9, where brush forest is assumed to contain 20.45 t C ha^{-1} (Düggelin and Abegg 2011).

Vineyards, Low-stem Orchards and Tree Nurseries (CC33)

Low-stem orchards are small fruit trees distinguished from CC35 ('orchards') by a maximum stem-height of 1 m and a much higher stand density. Only low-stem orchards and vineyards are considered in the following because no stand densities for tree nurseries are available. Data from SFSO (2002) indicate a very small contribution of tree nurseries (1'378 ha) as compared to the sum of vineyards (15'436 ha, SFSO 2005) and low-stem orchards (240 ha, based on Widmer 2006).

The standing carbon stock of living biomass per ha (Cl) for CC33 is therefore calculated as:

Cl = [(Cl vineyards * area vineyards) + (Cl low-stem orchards * area low-stem orchards)] / (area vineyards + area low-stem orchards)

Cl of vineyards is 3.61 t C ha^{-1}, calculated based on the mean stand density (5'556 vines ha^{-1}) and woody biomass of a plant including roots (0.65 kg C; Ruffner 2005).

For small fruit trees on low-stem orchards, no literature value was found for biomass expansion factors. Therefore, following assumptions were made. Diameter at breast height (DBH) of such trees was assumed to be around 10 cm and the stem height was assumed to be around 1 m. The bole shape of low-stem apple trees can be approximated by a cylinder shape.

Stem wood volume = r^2 * π * height = $(5\ cm)^2$ * 3.1 * 100 cm = 7.75 dm^3

Based on expert knowledge (Kaufmann 2005), the percentage of branches was estimated as 100%, and the percentage of roots was estimated as 30% of the stem wood volume. This results in a BEF of 2.3. A wood density of 0.55 kg dm^{-3} (Vorreiter 1949) and the default IPCC carbon content of 50% were assumed. With these assumptions the carbon content of a tree of the type low-stem ('Niederstamm') is calculated as follows:

C low-stem = stem wood volume * BEF * wood density * carbon content

= 7.75 dm^3 * 2.3 * 0.55 kg/dm^3 * 0.5 = 4.9 kg C

The mean stand density of low-stem orchards is estimated at 2500 ha^{-1} (Widmer 2006), resulting in a Cl of 12.25 t C ha^{-1}.

The resulting Cl for CC33 is 3.74 t C ha^{-1}.

Orchards (CC35)

Orchards are loosely planted larger fruit trees ('Hochstammobst') with grass understory. Cl of orchards trees is calculated as:

CI biomass = (carbon per fruit tree [t C] * number of fruit trees / area orchards [ha]) + carbon in grass [t C ha^{-1}]

The carbon content of a large fruit tree with a DBH of 25 - 35 cm was calculated as follows:

C (Hochstamm) = Stem wood volume * KE-Factor = 225 kg C

where:

Stem wood volume of an apple tree assuming a cylindrical stem with mean DBH of 30 cm and a stem height of 7 m amounts to 0.5 m^3;

KE-Factor [t C m^{-3}] = BEF * Density * C-content = 0.45, (Wirth et al. 2004: 68, Table 16).

From the total fruit-growing area of 41’480 ha (SFSO 2005), the area of small fruit trees (240 ha, see CC33) was subtracted, and the remaining area was divided by the number of large fruit trees. Large fruit trees were counted in 1991 (3’616’301) and 2001 (2’900’000; SFSO 2002), and the mean value was divided by 41’240 ha to obtain a mean stand density of 79 trees ha^{-1}. The resulting woody biomass of CC35 is thus 17.78 t C ha^{-1}. Because orchards typically have a grass understory, the biomass of CC31 was added to the woody biomass. Orchards are located below 1000 m a.s.l., so the mean of grass biomass of the classes <601 and 601-1200 m a.s.l. (i.e. 6.54 t C ha^{-1}; cf. Table 6-31) was taken to obtain a total biomass stock of 24.32 t C ha^{-1} for CC35.

Stony Grassland (CC36)

Approximately 35% of the surface of CC36 (herbs and shrubs on stony surfaces) is covered by vegetation. No accurate data were available for this category. Therefore, the carbon content of brush forest (20.45 t C ha^{-1}; cf. Chapter 6.4.2.9; Düggelin and Abegg 2011) was multiplied by 0.35 to account for the 35% vegetation coverage. This results in a carbon content of 7.16 t C ha^{-1}.

Unproductive Grassland (CC37)

The category CC37 includes grass and herbaceous plants at watersides of lakes and rivers including dams and other flood protection structures, constructions to protect against avalanches and rock slides, and alpine infrastructure (e.g. for skiing). For none of these land-use types, biomass data are currently available. Therefore, the mean value of permanent grasslands in all altitude zones, 7.01 t C ha^{-1} (cf. Table 6-31), is arbitrarily chosen as the preliminary biomass value for CC37.

6.6.2.2 Carbon in Soils

Permanent Grassland (CC31)

Carbon stocks in grassland soil refer to a depth of 0-30 cm.

Soil carbon stocks in mineral soils under permanent grassland CC31 are calculated based on Leifeld et al. (2003, 2005). The approach correlates measured soil organic carbon stocks (t ha^{-1}) for permanent grasslands with soil texture and elevation after correction for soil depth and stone content. Area upscaling makes use of the Swiss digital soil map (SFSO 2000a) and topography. Mean Cs values calculated for grasslands CC31 are given in Table 6-32.

It should be noted that the current C stocks are not only the result of the conditions for productivity and C turnover under different land-use types, but are also determined by farmers' decisions to use a site in a specific way due to the demands of a crop or the suitability of a site, e.g. regarding machine use (see Leifeld et al. 2003: 65).

Table 6-32 Mean carbon stocks under permanent grassland on mineral soils (0-30 cm).

Altitude [m]	**Cs [t C ha^{-1}]**
<601	62.02 ± 13
601-1200	67.50 ± 12
>1200	75.18 ± 9

Soil carbon stocks in organic soils under permanent grassland are calculated based on Leifeld et al. (2003, 2005). The approach uses measured carbon stocks in Swiss organic soils without differentiation among cropland and grassland. The mean soil organic carbon stock (0-30 cm) for organic soils is 240 ± 48 t C ha^{-1}.

Shrub Vegetation (CC32)

Due to the lack of data, the values of CC31 (Table 6-32) were used as the mineral soil carbon stocks for this category (0-30 cm).

The mean soil organic carbon stock (0-30 cm) for organic soils is 240 t C ha^{-1}.

Vineyards, Low-stem Orchards and Tree Nurseries (CC33)

The category includes carbon stocks in soils of vineyards, low-stem orchards and tree nurseries. In accordance to carbon stocks in biomass, only vineyards and low-stem orchards are considered. Both land-use types are assumed to have grass undercover in general. Therefore, the soil carbon content could be between the values for grassland and cropland. As a conservative assumption, the soil carbon content values of cropland, i.e. 53.40 t C ha^{-1} (mineral soils, 0-30 cm) and 240 t ha^{-1} (organic soils, 0-30 cm) are taken for CC33 (see Chapter 6.5.2.2).

Copse (CC34)

Due to the lack of data, the values of CC31 (Table 6-32) were used as the mineral soil carbon stocks for this category (0-30 cm).

The mean soil organic carbon stock (0-30 cm) for organic soils is 240 t C ha^{-1}.

Orchards (CC35)

Cs of orchards was calculated in accordance to the biomass calculation. No specific Cs orchards values are available, and the mean value of grassland mineral soil carbon stocks from the two lower altitudinal zones (i.e. 64.76 t C ha^{-1}; cf. Table 6-32) was taken for mineral soils (0-30 cm), and the value of 240 t ha^{-1} for organic soils (0-30 cm).

Stony Grassland (CC36)

Soil organic carbon stocks under herbs and shrubs on stony surfaces were calculated according to the procedure described in Chapter 6.6.2.1, i.e. it is assumed that not more than 35% of the area of CC36 is covered with vegetation and thus only 35% of the area bears a mineral soil while the remainder is bare rock. Land use of this category mostly belongs to 'grassland' and 'unproductive land' and likely includes many of the former alpine grasslands (SFSO 2005). These grasslands are mainly located at altitudes > 1200m a.s.l. Thus, using the respective value from Table 6-32, the carbon stock Cs of CC36 is calculated as:

Cs of CC36 = 0.35 * Cs permanent grassland > 1200 m = 26.31 t C ha^{-1} (0-30 cm)

The mean soil organic carbon stock (0-30 cm) for organic soils is 240 t C ha^{-1}. It is assumed that the small area covered by organic soils in CC36 (cf. CRF-table 4C1 'stony'), albeit entitled 'stony grassland', does not contain significant contributions from stones because bogs are free of stones as a matter of nature and fens usually contain, if any, only fine mineral sediments.

Unproductive Grassland (CC37)

The category CC37 ‚unproductive grasslands' includes grass and herbaceous plants at watersides of lakes and rivers including dams and other flood protection structures, constructions to protect against avalanches and rock slides, and alpine infrastructure (e.g. for skiing). For none of these land-use types, Cs data are currently available. Soil carbon stocks of CC37 'unproductive grassland' were arbitrarily set as the mean value of carbon stocks under permanent grassland on mineral soils (Table 6-32) in accordance to the procedure followed for biomass. Cs of CC37 is thus 68.23 t C ha^{-1}.

The mean soil organic carbon stock (0-30 cm) for organic soils is 240 t C ha^{-1}.

6.6.2.3 Changes in Carbon Stocks

Changes of carbon stock in biomass and in mineral soils are assumed to be zero for constant land use.

The annual net carbon stock change in organic soils on managed grassland (CC31, CC33 and CC35) was estimated to -9.52 t C ha^{-1} according to measurements in Europe including Switzerland as compiled by Leifeld et al. (2003, 2005) and rechecked by ART (2009b). For weakly managed grasslands (CC32, CC34, CC36 and CC37) the emission from organic soils was estimated to 5.30 t C ha^{-1} yr^{-1} according to available domestic data (ART 2011b).

In the case of land-use change, the net changes in biomass and soil of CC31, CC32, CC33, CC34, CC35, CC36, and CC37 are calculated as described in Chapter 6.1.3.

6.6.2.4 N_2O Emissions from Grassland

N_2O emissions from drainage of organic soils on grassland are reported in the agriculture sector.

The calculation of emissons for categories 4III and 4IV (N_2O from Nitrogen Mineralization in mineral soils) is described in Chapter 6.10.

6.6.2.5 Emissions from Wild Fires

Data on wildfires affecting Swiss grassland are obtained from cantonal authorities and are compiled by the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL, Swissfire database, http://www.wsl.ch/swissfire). Table 6-33 shows the annual burnt area from 1990 to 2013. The Swissfire database differentiates between 'grassland' and 'unmanaged land'. As a conservative assumption the sum of both categories is reported. Controlled burning is no common practice in Switzerland. Therefore, all fires are assigned to “wildfires”.

The resulting CH_4 and N_2O emissions were calculated according to Equations 3.2.19/3.2.20 of IPCC (2003):

- Emission CH_4 = (carbon released) * (emission ratio) * 16/12
- Emission N_2O = (carbon released) * (emission ratio) * 28/12
- carbon released = (burnt area) * (available fuel) * (combustion efficiency)

The "available fuel" was calculated as the area-weighted carbon stock in living biomass for all grassland categories (CC31 to CC37) as reported in FOEN (2014): 7.68 Mg C ha^{-1}. Applying a default combustion efficiency of 0.74 (IPCC 2003, Table 3A.1.12, savanna grassland) the average amount of carbon that could be released by wildfires on grasslands is 5.68 Mg C ha^{-1}.

For CH_4, the emission ratio of savannas was used: 0.004 (IPCC 1996, Table 4-15). The resulting mean emission is 0.030 Mg CH_4 ha^{-1}.

For N_2O, a N/C ratio of 0.015 (IPCC 1996, pp. 4.83) and an emission ratio of 0.007 (IPCC 2003, Table 3A.1.15) result in a mean emission of 0.00094 Mg N_2O ha^{-1}.

The resulting annual emissions 1990-2013 on burnt areas in 4C grasslands are shown in Table 6-33 and are reported in CRF-table 4(V).

Table 6-33 Area of Grassland affected by wildfires (WSL, Swissfire database) and resulting CH_4 and N_2O emissions, 1990-2013.

Year	Area burnt	CH_4	N_2O
	ha	t	t
1990	637	19.315	0.598
1991	22	0.676	0.021
1992	6	0.183	0.006
1993	17	0.513	0.016
1994	175	5.292	0.164
1995	82	2.485	0.077
1996	43	1.297	0.040
1997	373	11.302	0.350
1998	73	2.203	0.068
1999	19	0.574	0.018
2000	22	0.662	0.020
2001	8	0.227	0.007
2002	257	7.799	0.241
2003	138	4.181	0.129
2004	4	0.130	0.004
2005	4	0.116	0.004
2006	6	0.171	0.005
2007	88	2.656	0.082
2008	29	0.879	0.027
2009	3	0.083	0.003
2010	1	0.040	0.001
2011	56	1.706	0.053
2012	4	0.133	0.004
2013	3	0.102	0.003

6.6.2.6 NMVOC Emissions

Estimates for annual biogenic emissions of NMVOC (CRF-table 4) for forests and natural grassland in Switzerland are available in SAEFL (1996a): the value for natural grassland (unproductive vegetation) is 0.51 kt.

6.6.3 Uncertainties and Time-Series Consistency

A range of possible carbon stock changes in mineral soils has been determined by the Swiss Soil Monitoring Network (NABO). The upper and lower margin of the 95% confidence interval for carbon stock changes under grassland is 0 ± 0.57 t C ha^{-1} (Keller 2013). This absolute uncertainty is used to calculate relative uncertainties for 4C1 and 4C2 by dividing with the mean net emission per hectare of 4C1 and 4C2, respectively. In 2013, the mean net emissions were 0.025 t C ha^{-1} for 4C1 and 0.787 t C ha^{-1} for 4C2 (calculated from CRF-table 4C). The resulting relative uncertainties are 2316% for 4C1 and 72% for 4C2, respectively (Table 6-5).

In the uncertainty analysis, these values were chosen for the overall emission factor uncertainties for CO_2 in sectors 4C1 and 4C2 as they dominate the other sources of uncertainty by far:

- Uncertainties for soil carbon stocks are given together with the mean value in the text above: 12-21% for mineral soils and 20% for organic soils. They take into account uncertainties in measured carbon contents and predicted soil bulk densities, i.e., they consider only uncertainties in emission factors.
- The uncertainty of the carbon stock change in organic soils of intensly managed grassland is 23% as reported by Leifeld et al. (2003: 56). For weakly managed grassland this uncertainty is 117% according to ART 2011b.
- The relative uncertainty in yield determination has been estimated at 13% for biomass carbon from both cropland and grassland (Leifeld and Fuhrer 2005). Data on biomass yields for different elevations and management intensities as published by FAL/RAC (2001) are based on many agricultural field experiments and have a high reliability.

Uncertainties of activity data of category 4C Grassland are described in Chapter 6.3.3. For wildfires, the emission factor uncertainties of CH_4 and N_2O were set to 70% (identical to forest land, see Chapter 6.4.3).

Consistency: Time series for Grassland are all considered consistent; they are calculated based on consistent methods and homogenous databases.

6.6.4 Category-Specific QA/QC and Verification

The general QA/QC measures are described in Chapter 1.2.3.

Changes in Living Biomass

The assumption of a constant carbon stock in living biomass has been reconsidered (UNFCCC 2007: §97). According to Schneider (2010) yields on meadows and pastures did not increase since 1990. Neither management nor the share of clover did significantly change over the past 20 years. Consequently, the current approach has been reconfirmed.

In 2012 an assessment of the appropriateness of the estimated pools of carbon in living biomass was conducted (ART 2012a). It came to the conclusion that almost all carbon stocks and carbon stock changes are in the expected range of the IPCC Guidelines and Good Practice Guidance. Nevertheless there is room for improvements. However, given the relatively low significance of the respective emissions a major effort in this area is hardly justified. Consequently, the biomass carbon pools will eventually be recalculated only in the course of the new planned Tier 3 approach for quantification of carbon stocks and carbon stock changes in agricultural soils (see Chapter 6.6.6).

Changes in SOC Pools

A SOC pool dataset provided by the Swiss Soil Monitoring Network (NABO; see Chapter 6.4.4) supports the Tier 1 assumption that changes of carbon stocks in mineral soils are zero for grassland remaining grassland (cf. UNFCCC 2007: §97). The SOC pool measured at 33 grassland monitoring sites in the Swiss Soil Monitoring Network showed in average a slight increase during the period 1985 to 2000 and a slight decrease thereafter (Figure 6-8). SOC pools ranged between 20.9 and 183.2 t C ha^{-1}, the average SOC pool for the 33 grassland monitoring sites was 77.9 t C ha^{-1} (0-20 cm). Two alpine grassland sites above 1200 m a.s.l showed remarkable SOC pools of about 120 and 173 t C ha^{-1} (0-20 cm). The confidence interval of the mean SOC pool versus time was ± 0.9 t C ha^{-1}. In total, the results of the soil monitoring data indicate that Swiss grassland mineral soils did not act as a net source or sink of carbon during the last 20 years.

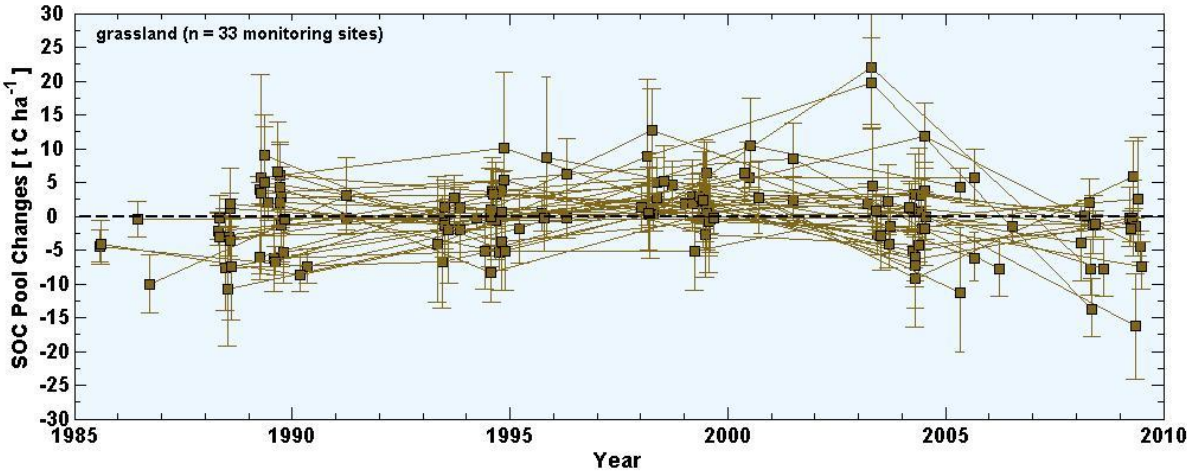


Figure 6-8 Time series of measured SOC pool changes in the top soil (0-20 cm) at the 33 NABO grassland sites from the 1st to the 5th re-sampling campaigns. SOC pools were centred by the median SOC pool of all re-samplings of the monitoring site. Each pool value presents the median of four bulked soil samples per campaign with measured SOC and bulk density. The error bars indicate the 25% and 75% percentiles resulting from the spatial variation of the sites and the errors along the measurement chain. The altitude of the grassland sites ranges between 265 and 2340 m a.s.l.

The slight increase and decrease will be subject for further detailed analysis. Partly, it may be attributed to natural variation of soil sampling (see Chapter 6.4.4). Furthermore, we presume that at grassland sites with intensive management and large manure application the temporal change of the SOC content is partly related to the nitrogen input fluxes and nitrogen content in soil. Therefore, the total nitrogen content of the archived soil samples will be measured and the correlation to the SOC content analysed. Moreover, management data of the monitoring sites gathered directly from the farmers since 1985 permit the calculation of annual nutrient fluxes of the sites (Keller et al. 2005). In this way temporal changes in nutrient management of the grassland sites can be separated from other effects that may cause temporal changes of SOC contents in grassland soils.

Short-term Land-Use Changes between Grassland and Cropland

See comments in Chapter 6.5.4.

6.6.5 Category-Specific Recalculations

The carbon stock in living biomass of brush forests was revised based on Düggelin and Abegg (2011), cf. Chapter 6.4.2.9. As a consequence, carbon stocks of the combination categories CC32, CC34 and CC36 were adjusted for all years.

6.6.6 Category-Specific Planned Improvements

Information about carbon stock changes in soils for grassland remaining grassland will become available from Agroscope research activities. A pilot study to evaluate possible Tier 3 methodological approaches for quantification of carbon stocks and carbon stock changes in agricultural soils (including meadows and pastures) (cf. UNFCCC 2007: §97) has recently been terminated (Köck et al. 2013).

A new study on GHG emissions from peatlands and organic soils under different land use (Agroscope in collaboration with the University of Basel, 2013-2016, financed by FOEN) will improve the robustness of domestic emission factor estimates for soils rich in organic matter in the medium term.

Projects in a new national research programme ("Sustainable Use of Soil as a Resource", http://www.nfp68.ch/E) focus on (1) sustainable management of organic soils, (2) agricultural management and below ground carbon inputs, and (3) an integrated modelling framework to monitor and predict trends of agricultural management and their impact on soil functions at multiple scales. In the long term, results from these studies are expected to improve the reporting of emissions by sources and removals by sinks in category 4C.

6.7 Category 4D – Wetlands

6.7.1 Description

Approach 2 Key category 4D1
CO_2 from Wetlands remaining Wetlands (trend).

The category 4D2 Land converted to Wetlands is not a key category.

Wetlands consist of surface waters (CC41) and unproductive wet areas such as shore vegetation, fens or (raised) bogs (CC42), see Table 6-2 and Table 6-6.

6.7.2 Methodological Issues

6.7.2.1 Carbon in Living Biomass

Surface Waters (CC41)

Surface waters have no carbon stocks by definition.

Unproductive Wetland (CC42)

CC42 consists of unmanaged or weakly managed grassland, bushes or tree groups. The pool of living biomass was estimated to 6.50 t C ha^{-1} (Mathys and Thürig 2010).

6.7.2.2 Carbon in Soils

In general, the soil carbon stock for surface waters (CC41) is zero. However, for CC41 situated in areas with organic soil (see Chapter 6.2.2 and Table 6-7), the soil carbon stock is set to 240 t C ha^{-1} (0-30 cm). These surface waters are assumed to be shallow ponds as integrated parts of fens or bogs.

Land cover in CC42 includes bogs and fens protected by Federal Legislation (Swiss Confederation 1991a, 1994) as well as reed. More than 10% of the unproductive wetland are located on organic soils (cf. Table 6-7) as defined in Chapter 6.2.2. In this case the carbon stock in soils is 240 t C ha^{-1} (0-30 cm). Currently, no specific soil data are available for CC42 on mineral soils. As a first guess, it is suggested that the soil carbon stock of unproductive wetlands is similar to unproductive grassland (CC37) on mineral soils (mean value: 68.23 t C ha^{-1}; 0-30 cm).

6.7.2.3 Changes in Carbon Stocks

Changes of carbon stock in biomass and in mineral soils are assumed to be zero for wetlands remaining wetlands.

The emission from organic soils under CC41 is assumed to be zero because the respective areas are not drained.

The emission from organic soils under CC42 was estimated to 5.30 t C ha^{-1} yr^{-1} according to domestic data (ART 2011b). This value is used for weakly managed ecosystems such as fens and unmanaged ecosystems such as raised bogs. Bogs and fens are protected to a large part by Federal Ordinances (Swiss Confederation 1991a, 1994) and drainage is therefore not allowed. However, the impact of old drainages constructed before 1990 probably leads to a certain emission.

In the case of land-use change, the net changes in biomass and soil of both CC41 and CC42 are calculated as described in Chapter 6.1.3.

For land converted to unproductive wetland (CC42) a conversion time of one year was chosen for the carbon stock change in living biomass and in dead organic matter (see Table 6-3). This was done because at the moment when the land-use change is detected in the sense of changes in the vegetation cover on the AREA aerial photographs the land-use change has already occurred (cf. UNFCCC 2009: §82). For carbon stock changes in soil the conversion time is 20 years.

6.7.2.4 Non CO_2 Emissions from Wetlands

An estimate of 0.43 kt CH_4 yr^{-1} emitted by reservoirs (flooded lands) is given by Hiller et al. (2014). The estimate encompasses 97 artificial lakes covering a total area of 10.6 kha. This emission is reported in CRF-table 4(II)D.2.

N_2O emissions from drainage of organic soils was calculated for unproductive wetlands (CC42) and reported in CRF-Table 4(II)D.3. The emission factor of 1.6 kg N_2O-N ha^{-1} used is the default value given in the IPCC Wetlands Supplement (IPCC 2014a, Table 2.5) for shallow drained, nutrient-rich grassland.

The calculation of emissons for categories 4(III) and 4(IV) (N_2O from Nitrogen Mineralization in mineral soils) is described in Chapter 6.10.

6.7.3 Uncertainties and Time-Series Consistency

As a best guess, a value of 50% was chosen for the overall emission factor uncertainty in sector 4D. The uncertainty of the emission factor for carbon stock losses in organic soils is 100% based on monitoring values compiled by ART (2011b) (cf. Table 6-5).

The uncertainty for CH_4 emitted by flooded lands can be very high (ICPP 2004, Volume 4, Appendix 3). As a best guess, a value of 70% was chosen for the emission factor of 4IV2 (cf. Table 6-5).

For N_2O emissions from drainage of organic soils the uncertainties for agricultural soils given in the 2006 IPCC Guidelines is used. The arithmetic mean of the lower and upper bound uncertainty (137.5%) is used for the emission factor (see also Chapter 5.5.3).

Uncertainties of activity data of category 4D Wetlands are described in Chapter 6.3.3.

Consistency: Time series for Wetlands are all considered consistent; they are calculated based on consistent methods and homogenous databases.

6.7.4 Category-Specific QA/QC and Verification

The general QA/QC measures are described in Chapter 1.2.3.

No category-specific QA/QC activities have been carried out.

6.7.5 Category-Specific Recalculations

N_2O emissions from drained organic soils are reported for the first time on unproductive wetlands (in category 4(II)).

6.7.6 Category-Specific Planned Improvements

A new study on GHG emissions from peatlands and organic soils under different land use (Agroscope in collaboration with the University of Basel, 2013-2016, financed by FOEN) will improve the robustness of domestic emission factor estimates for soils rich in organic matter in the medium term.

Lake Wohlen, a hydroelectric reservoir on the Swiss Plateau, has been shown to be a large emitter of CH_4 (DelSontro et al. 2010). Sediments cores from the reservoir were sampled in March 2014 by the University of Bern. The project (2014-2015, co-financed by FOEN) focuses on the question if Lake Wohlen is a representative system within Switzerland.

6.8 Category 4E – Settlements

6.8.1 Category Description

Approach 1 Key category 4E2

CO_2 from Land converted to Settlements (level and trend)

Approach 2 Key category 4E2

CO_2 from Land converted to Settlements (level and trend)

The category 4E1 Settlements remaining Settlements is not a key category.

Settlements consist of buildings/constructions (CC51), herbaceous biomass in settlements (CC52), shrubs in settlements (CC53), and trees in settlements (CC54) as shown in Table 6-2 and in Table 6-6.

6.8.2 Methodological Issues

6.8.2.1 Carbon in Living Biomass

Buildings and Constructions (CC51)

Buildings/constructions contain no carbon by default.

Herbaceous Biomass, Shrubs and Trees in Settlements (CC52, CC53, CC54)

Carbon stocks in living biomass are: 9.54 t C ha^{-1} for CC52, 15.43 t C ha^{-1} for CC53, and 20.72 t C ha^{-1} for CC54 (Mathys and Thürig 2010: Table 7).

6.8.2.2 Carbon in Soils

The carbon stock in soil for CC51 (buildings and construction) was set to zero.

In case of land-use changes to CC51 or from CC51, 50% of the difference between carbon stocks before and after the change is reported as a source or sink, respectively. The reason for this is that the soil organic matter on construction sites is stored temporarily and is later used for replanting the surroundings or for vegetating dumps, for example. According to paragraph 7 of the "Ordinance against deterioration of soils" (Swiss Confederation 1998) the soil material excavated on a construction site must be treated in such a way that it can be used as a soil again. When the material is re-used (e.g. for re-cultivations) the fertility of the soil must not be affected. This regulation ensures that a large part of the soil organic matter is preserved on land converted to and from CC51.

Prior to 1998 there were federal acts and good practice guidance for engineers focusing on physical soil protection and on preserving soil fertility. The Ordinance against pollution of soils (Swiss Confederation 1986) was in force between 1986 and 1998 (without a specific focus on the soil material on construction sites). As a legal basis the Federal Act on the

Protection of the Environment (Swiss Confederation 1983) formulates the aim of preventing soil pollution (“physical, chemical and biological modification of the natural condition of the soil”) and of preserving the natural foundations of life sustainably, in particular biological diversity and the fertility of the soil. The act and concomitant ordinances form a legal framework for prosecuting violators. It is very likely that also prior to the latest environmental legislation the protection measures at construction sites were applied in an appropriate way as the awareness for soil fertility has been traditionally high in Switzerland. A good practice guidance of the Swiss Society of Engineers and Architects on gardening and landscaping operations may serve as example (SIA 1988).

Switzerland has chosen the factor 0.5 (i.e. 50% stabilised SOC fraction which is not likely to be oxidised in the medium term) to reflect this domestic soil protection measure (see discussion in Leifeld et al. 2003: 67). Thus, the equation 6.8 presented in Chapter 6.1.3.2 is adjusted as follows if a=CC51 or b=CC51:

deltaCs,i,ba = [0.5 * (stockCs,i,a – stockCs,i,b) / CT] * Ai,ba

where:

a	land-use category after conversion (CC = a)
b	land-use category before conversion (CC = b)
ba	land use conversion from b to a
i	spatial stratum
Ai,ba	area of land (ha) converted from b to a in the spatial stratum i
CT	conversion time (yr), see Table 6-3.

The carbon stock in mineral soils for CC52, CC53, and CC54 is 53.40 t C ha^{-1} (0-30 cm). This is the same value as for cropland.

For organic soils the carbon stock is 240 t C ha^{-1} (0-30 cm). This is the same value as for all other combination categories.

6.8.2.3 Changes in Carbon Stocks

Changes of carbon stock in biomass and in mineral soils are assumed to be zero for settlements remaining settlements.

On organic soils, the following emission factors were applied:

- 9.52 t C ha^{-1} yr^{-1} for CC52. This corresponds to the value used for cropland because CC52 areas are managed (gardens, parks) (Leifeld et al. 2003, 2005 and rechecked by ART 2009b).
- 5.30 t C ha^{-1} yr^{-1} for CC53 and CC54. This corresponds to the value used for weakly managed grasslands (ART 2011b).

In the case of land-use change, the net changes in biomass and soil of CC51, CC52, CC53, and CC54 are calculated as described in Chapter 6.1.3.

6.8.2.4 N_2O Emissions from Settlements

The calculation of emissons for categories 4III and 4IV (N_2O from Nitrogen Mineralization in mineral soils) is described in Chapter 6.10.

6.8.3 Uncertainties and Time-Series Consistency

As a best guess, a value of 50% was chosen for the overall emission factor uncertainty in sector 4E (Table 6-5).

Uncertainties of activity data of category 4E Settlements are described in Chapter 6.3.3.

Consistency: Time series for Settlements are all considered consistent; they are calculated based on consistent methods and homogenous databases.

6.8.4 Category-Specific QA/QC and Verification

The general QA/QC measures are described in Chapter 1.2.3.

No category-specific QA/QC activities have been carried out.

6.8.5 Category-Specific Recalculations

There were no recalculations.

6.8.6 Category-Specific Planned Improvements

There are no planned improvements.

6.9 Category 4F – Other Land

6.9.1 Description

The categories 4F1 Other Land remaining Other Land and 4F2 Land converted to Other Land are not key categories.

As shown in Table 6-2 and in Table 6-6 other land (CC61) covers non-vegetated areas such as glaciers, rocks and shores.

6.9.2 Methodological Issues

By definition, other land has no carbon stocks. Coherently, changes of carbon stock in biomass and in soil are assumed to be zero for other land remaining other land.

In the case of land converted to other land, the net C changes in biomass and soil are calculated as described in Chapter 6.1.3.

The calculation of emissons on land converted to other land for categories 4III and 4IV (N_2O from Nitrogen Mineralization in mineral soils) is described in Chapter 6.10.

6.9.3 Uncertainties and Time-Series Consistency

As a first guess, a value of 50% was chosen for the overall emission factor uncertainty in sector 4F2 (Table 6-5).

Uncertainties of activity data of category 4F Other Land are described in Chapter 6.3.3.

Consistency: Time series for Other Land are all considered consistent; they are calculated based on consistent methods and homogenous databases.

6.9.4 Category-Specific QA/QC and Verification

The general QA/QC measures are described in Chapter 1.2.3.

No category-specific QA/QC activities have been carried out.

6.9.5 Category-Specific Recalculations

There were no recalculations.

6.9.6 Category-Specific Planned Improvements

There are no planned improvements.

6.10 Categories 4III, 4IV – N_2O from Nitrogen Mineralization

6.10.1 Description

This chapter presents the methods for calculating direct (4III) and indirect (4IV) N_2O emissions from nitrogen (N) mineralization in mineral soils. The source of nitrogen is N mineralization associated with loss of soil organic matter resulting from land-use change.

- In category 4III, direct N_2O emissions on land converted to forest land, cropland, grassland, wetlands, settlements or other land are reported.
- In category 4IV2, indirect emissions of N_2O due to nitrogen leaching and run-off are reported.

The following N_2O emissions were included in the agriculture sector:

- N_2O emissions associated with inputs from N fertilizers (CRF table 4(I); see Chapter 5.5).

- N_2O emissions on cropland remaining cropland and on grassland remaining grassland (CRF table 4(III), see Chapter 5.5). In Switzerland, grassland also belongs to the agricultural area.
- Indirect N_2O emissions due to atmospheric deposition (CRF table 4(IV1), see Chapter 5.3).

6.10.2 Methodological Issues

Direct N_2O emissions (4III) as a result of the disturbance of mineral soils associated with land-use change are calculated according to IPCC (2006, Chapter 4_11):

Emission(N_2O) = – deltaCs * 1 / (C:N) * EF1 * 44 / 28, if deltaCs < 0 [kt N_2O]

where:

deltaCs: soil carbon change induced by land-use change [kt C]

C:N: C to N ratio of the soil before the land-use change

EF1: default emission factor = 0.01 kg N_2O-N (kg N)$^{-1}$, IPCC 2006 (Table 4_11.1)

deltaCs is calculated according to the methodology described in Chapter 6.1.3.2. If deltaCs is zero or positive (carbon gain) there are no N_2O emissions provoked by a land-use change.

The value of the C:N ratio is related to the land-use category before the change. For cropland and grassland the ratio is 9.8 according to Leifeld et al. (2007). This value was also used for the mineral soils in wetlands (CC42) and unsealed settlement areas (CC 52, 53, 54). For forest land, the default value of C:N=15 was used (IPCC 2006, Equation 4_11.8).

The indirect N_2O emissions (4(IV)) as a result of N leaching and run-off are calculated as follows using default emission factors (IPCC 2006, Table 4_11.3):

Emission(N_2O) = – deltaCs * Frac / (C:N) * EF5 * 44 / 28, if deltaCs < 0 [kt N_2O]

where:

Frac: fraction of mineralized N lost by leaching or run-off, Frac=30%

EF5: default emission factor = 0.0075 kg N_2O-N (kg N)$^{-1}$, IPCC 2006 (Table 4_11.3)

If deltaCs is zero or positive (carbon gain) there are no N_2O emissions provoked by a land-use change. As the approach applied is not tier 3, no N_2O immobilization is reported.

For calculating deltaCs, all land-use changes and conversions between land-use subcategories were taken into account. Cropland remaining cropland is reported in the agriculture sector as prescribed in CRF table 4(III) in footnote 1. For Switzerland, also the N_2O emissions for grassland remaining grassland are reported in the agriculture sector as as grassland is part of the agricultural land.

On productive forest land (CC12), there are small yearly changes in soil carbon contents calculated with the Yasso07 model (Chapter 6.4.2.8). These changes are deliberately not considered for the calculation of N_2O emissions in categories 4(III) and 4(IV) as they are not associated with a land-use change or any change in management.

6.10.3 Uncertainties and Time-Series Consistency

Relative uncertainties for the emission factors were derived from the uncertainty ranges listed by IPCC 2006 (Tables 4_11.1 and 4_11.3) by calculating the average of the upper and the lower limit of the ranges:

Uncertainty (EF1): 135%
Uncertainty (EF5): 162%

The uncertainty of the activity data for category 4III corresponds to the uncertainty of the area converted to cropland or to grassland as shown in Table 6-10: 6% (in both cases).

The uncertainty of the activity data for category 4(IV2) is adopted from the agriculture sector (32%).

Consistency: Time series for Nitrogen Mineralization are all considered consistent; they are calculated based on consistent methods and homogenous databases.

6.10.4 Category-Specific QA/QC and Verification

The general QA/QC measures are described in Chapter 1.2.3.

No category-specific QA/QC activities have been carried out.

6.10.5 Category-Specific Recalculations

Category 4(III): N_2O emissions from mineralisation of organic matter in mineral soils due to land-use changes were adopted to the requirements of IPCC (2006). The new default emission factor was applied: 0.01 kg N_2O-N (kg N)$^{-1}$ instead of 0.0125 kg N_2O-N (kg N)$^{-1}$.

Category 4(IV): Indirect N_2O emissions due to leaching and run-off of nitrogen are reported for the first time. The following source of N input was included: N mineralization associated with loss of soil organic matter resulting from land-use change on mineral soils, excluding cropland remaining cropland and grassland remaining grassland.

6.10.6 Category-Specific Planned Improvements

There are no planned improvements.

6.11 Category 4G – Harvested Wood Products (HWP)

6.11.1 Description

Approach 1 Key category 4G

CO_2 from harvested wood products (trend).

Approach 2 Key category 4G

CO_2 from harvested wood products (trend).

The data presented in this chapter are estimates of net emissions and removals from HWP due to changes in the HWP carbon pool.

The applied approach to HWP accounting could be generally characterized as a production approach as described in Chapter 12, Volume 4 of IPCC (2006). Changes in carbon stocks in Swiss forests are estimated in Chapter 6.4 and changes in the wood products pool containing products made from wood harvested in Switzerland are described in this chapter. The wood products pool also includes products made from domestic harvest that are exported and stored in uses in other countries.

The estimate uses the product categories, half lives, and methodologies as described in IPCC (2006) and IPCC (2014).

6.11.2 Methodological Issues

The same methodology is used for reporting under UNFCCC and accounting under KP for HWPs in Switzerland and is based on Decision 2/CMP.7, paragraph 29, namely, that "transparent and verifiable activity data for harvested wood products categories are available, and accounting is based on the change in the harvested wood products pool of the second commitment period, estimated using the first-order decay function".

For the estimation of carbon stocks and carbon stock change, the equations described in IPCC (2014) were used.

A Tier 1 approach, instantaneous oxidation, was applied to the product category paper because the available statistical data are poor due to uncertainties on estimating how much of the national harvest is responsible for the paper products, the factor of recycling, and that the contributrion of this product is too negligible to justify the (financial) effort (see Figure 4.1 in Volume 1 of IPCC 2006).

A Tier 2 approach, first order decay, was applied to the product categories panels and sawnwood, according to equation 2.8.5 in IPCC (2014).

- Emissions occurring during the second commitment period from HWPs removed from forests prior to the start of the second commitment period were also accounted for.The starting year used to estimate the delayed emissions from the existing pool is 1900.
- The feedstock from domestic harvest is calculated according to equation 2.8.1 in IPCC (2014).

- The change in carbon stocks was estimated separately for each product category and differentiating HWPs originating from Afforestation and from Forest Management (here KP-definitions are refered to as defined in Chapter 11.2.3) by applying equation 2.8.4 in IPCC (2014). Instantaneous oxidation was applied to HWPs originating from deforestations, which results in a conservative estimate of carbon stock changes in the HWP-pool.

6.11.2.1 Activity Data

Activity data for production of HWPs for the product categories sawnwood and wood panels are based on national statistics (FOEN 2014h) and FAO forest product statistics (Food and Agriculture Organization of the United Nations: forest product statistics, http://faostat3.fao.org/download/F/FO/E) and are described in detail in FOEN (2015i). The time series is shown in the CRF-Table 4G. For the second commitment period, activity data are restricted exclusively to Swiss national statistics.

Data on production of sawnwood is derived from national saw mill statistics (FOEN 2014h). Data on production of wood panels is derived from surveys of the processing industries (FOEN 2014h). In order to estimate the share of industrial roundwood originating from domestic forests, as feedstock for HWP production, data from National Wood Use statistic and National Foreign Trade statistics is used (FOEN 2014h).

In order to estimate carbon amounts in each HWP category and sub-category, default conversion factors are based on the values in IPCC (2014; table 2.8.1).

6.11.2.2 Emission Factors

Emission factors for specific product categories were calculated with default half-lives of 25 years for wood panels and 35 years for sawn wood (IPCC 2014).

6.11.2.3 Results

Gains and losses per product category are listed in Table 6-34 and Figure 6-9 shows the resulting emissions and removals.

Table 6-34 Greenhouse gas emissions (positive sign) and removals (negative sign) from Harvested Wood Products from forest land of land under Forest Management (4G under UNFCCC; Art. 3.4 under KP) between 1999 and 2013, in kt CO_2. HWPs originating from wood harvested at land converted from forest land to non forest land (UNFCCC) or from Deforestations (KP) are not taken into account.

Greenhouse gas emissions and revomals	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
	Net CO_2 equivalent emissions/removals (kt CO_2)							
HWP: 4G (UNFCCC) / Article 3.4 (KP)	**-485.54**	**-837.52**	**-582.32**	**-453.53**	**-448.75**	**-644.41**	**-771.69**	**-633.43**
gains sawnwood	-1158.14	-1290.96	-1087.82	-1031.30	-1016.08	-1157.94	-1233.57	-1225.09
gains wood panels	-550.38	-780.05	-747.06	-688.54	-709.66	-774.15	-840.78	-728.89
losses sawnwood	855.59	861.31	869.51	873.58	876.46	878.98	884.25	890.88
losses wood panels	367.39	372.18	383.05	392.72	400.53	408.70	418.42	429.68

Greenhouse gas emissions and revomals	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	
	Net CO_2 equivalent emissions/removals (kt CO_2)							
HWP: 4G (UNFCCC) / Article 3.4 (KP)	**-741.76**	**-524.55**	**-479.46**	**-509.57**	**-369.81**	**-299.55**	**-158.15**	
gains sawnwood	-1191.77	-1145.13	-1094.15	-1087.72	-990.30	-878.26	-782.03	
gains wood panels	-884.81	-731.73	-749.49	-797.14	-766.87	-817.68	-780.52	
losses sawnwood	897.22	902.78	907.27	910.70	913.96	915.28	914.39	
losses wood panels	437.60	449.52	456.91	464.60	473.40	481.12	490.02	

Fluctuations in the HWP-pool can mainly be attributed to changes in the production of sawnwood (see Table 6-35), which is strongly linked with the domestic harvesting rate.

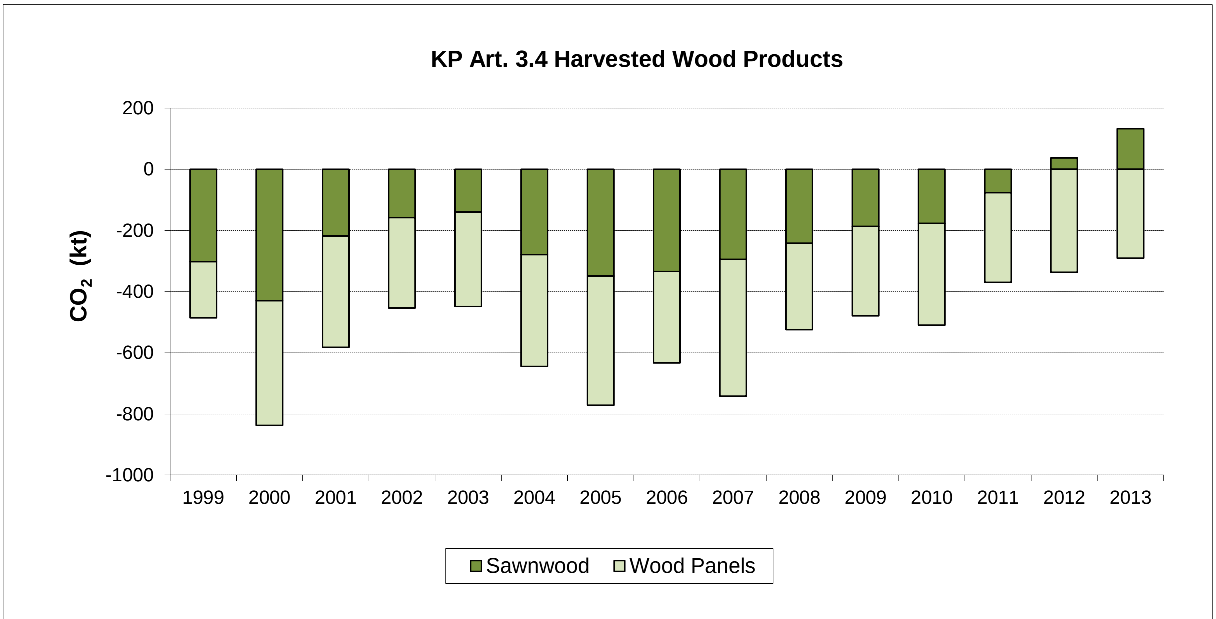


Figure 6-9 Switzerland's greenhouse gas emissions (positive sign) an removals (negative sign) from Harvested Wood Products between 1990 and 2013 originating from forest land (UNFCCC) or land under Forest Management (KP), in kt CO_2 eq.

6.11.3 Uncertainties and Time-Series Consistency

For category 4G HWP, the following information on relative uncertainty was used:

- Activity data

  Roundwood harvest: 5% (national activity data from the Swiss Forestry Statistics, annual complete survey) HWP Production:

Sawnwood: 5% for activity data prior to 1990 and 2% for activity data since 1990 (national activity from survey on wood processing in sawmills, combined survey, FOEN 2014h)

Wood Panels: 4% for activity data prior to 1990 and 2% for activity data since 1990 (national activity from survey in the wood industry, FOEN 2014h)

- Conversion factors:

  Wood density: 25% (default from IPCC 2006)

  Carbon contents in wood products: 10% (Lamlom and Savidge 2003, assessment of carbon content in wood)

- Emission factors (half-life estimates): 50% (default from IPCC 2006)

The total relative uncertainty of carbon losses and gains in HWP can be calculated as:

$$U_{HWP}\text{Sawnwood} = \sqrt{5^2 + 5^2 + 25^2 + 10^2 + 50^2} = 57\%$$

$$U_{HWP}\text{Panels} = \sqrt{5^2 + 4^2 + 25^2 + 10^2 + 50^2} = 57\%$$

Consistency: Time series for HWP are all considered consistent.

6.11.4 Category-Specific QA/QC and Verification

The general QA/QC measures are described in Chapter 1.2.3.

No category-specific QA/QC activities have been carried out.

6.11.5 Category-Specific Recalculations

There were no recalculations since category 4G HWP was not reported previously. HWP-specific improvements leading to technical correction of the FMRL are described in Chapter 11.7.4.

6.11.6 Category-Specific Planned Improvements

To improve the data on HWP generated from domestic harvesting, a new category will be added which will specify the amount of domestic wood used for HWP production.

7 Waste

7.1 Overview

7.1.1 Greenhouse Gas Emissions

Within the waste sector, emissions from five source categories are considered:

- 5A Solid waste disposal
- 5B Biological treatment of solid waste
- 5C Waste incineration and open burning of waste
- 5D Wastewater treatment and discharge
- 5E Other

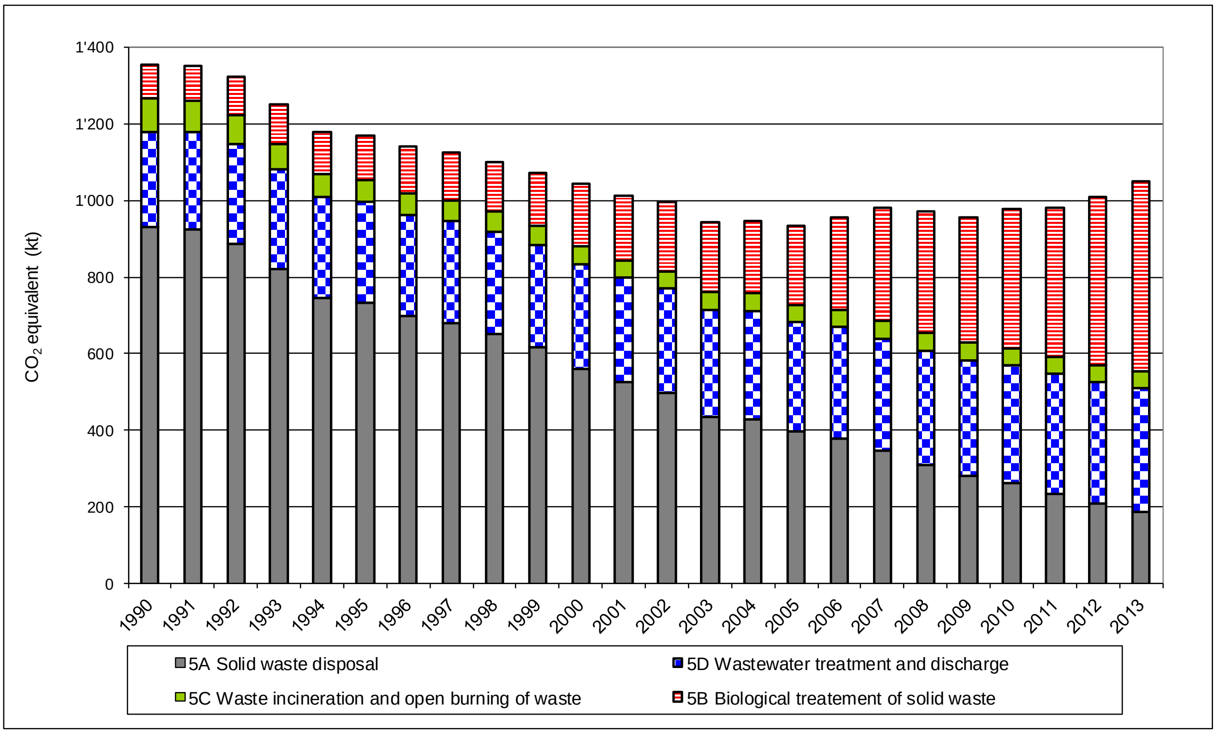


Figure 7-1 Switzerland's greenhouse gas emissions from sector 5 Waste 1990–2013. There are no greenhouse gas emissions from sector 5 E Other.

Table 7-1 Trend of total GHG emissions from sector 5 Waste in Switzerland 1990–2013.

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	CO_2 equivalent (kt)									
CO_2	63	60	56	50	41	36	32	30	28	24
CH_4	1150	1150	1123	1059	995	991	962	946	924	900
N_2O	142	144	146	143	144	146	148	150	151	151
Sum	1355	1354	1324	1253	1181	1173	1142	1126	1103	1076

Gas	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	CO_2 equivalent (kt)									
CO_2	21	18	14	13	13	12	13	12	12	11
CH_4	868	838	824	767	765	754	774	795	783	765
N_2O	158	157	161	166	170	169	173	177	179	184
Sum	1046	1013	999	947	948	935	960	984	974	959

Gas	2010	2011	2012	2013
	CO_2 eq (kt)			
CO_2	11	11	10	10
CH_4	780	778	805	841
N_2O	189	194	197	202
Sum	981	983	1013	1053

As illustrated in Table 7-1, in the waste sector a total of 1053 kt CO_2 equivalents were emitted in the year 2013. 18.2% stem from category 5A Solid waste disposal, 46.9% from category 5B Biological treatment of solid waste, 4.3% from category 5C Waste incineration and open burning of waste, and 30.6% from category 5D Wastewater treatment and discharge.

The total greenhouse gas emissions in the waste sector show a decrease of 22.3% from 1990 until 2013. From 1990–2002, the greenhouse gas emissions have been clearly dominated by solid waste disposal (more than 50% of total emissions). Later, the emissions from biological treatment of wastewater became more important. Since 2009 biological treatment of solid waste has been the most important source category.

CH_4 is the most important greenhouse gas in the waste sector over the whole period 1990–2013, contributing 79.9% to total greenhouse gas emissions in this sector. Nevertheless, CH_4 emissions have decreased from 1990 until 2013 by 26.9%. Two processes determine the trend: a dominating decreasing trend from solid waste disposal and a distinct increasing trend from 5B Biological treatment of solid waste as can be seen from Figure 7-3 and from Table 7-11 and which is caused by increasing activities of digestion and composting. N_2O emissions continue to increase from 142 kt CO_2eq in 1990 to 202 kt CO_2eq in 2013. This increase of 42.6% is mainly caused by the increasing number of inhabitants and related emissions from wastewater treatment. CO_2 is of minor importance in the waste sector. Its emissions decreased over the whole period 1990–2013 from 63 kt to 10 kt, corresponding to a reduction of 84%. The share of CO_2 on total greenhouse gas emissions in the waste sector dropped from 5% in 1990 to 1% in 2013.

The relative trends of the gases are shown in Figure 7-2.

Please note that according to IPCC Good Practice Guide all emissions from waste-to-energy, i.e. emissions resulting when waste material is used directly as fuel or converted into a fuel, are reported under sector 1 Energy (see also Figure 7-4). Therefore, the largest share of waste-related emissions in Switzerland is not reported under sector 5 Waste, as illustrated in the box below.

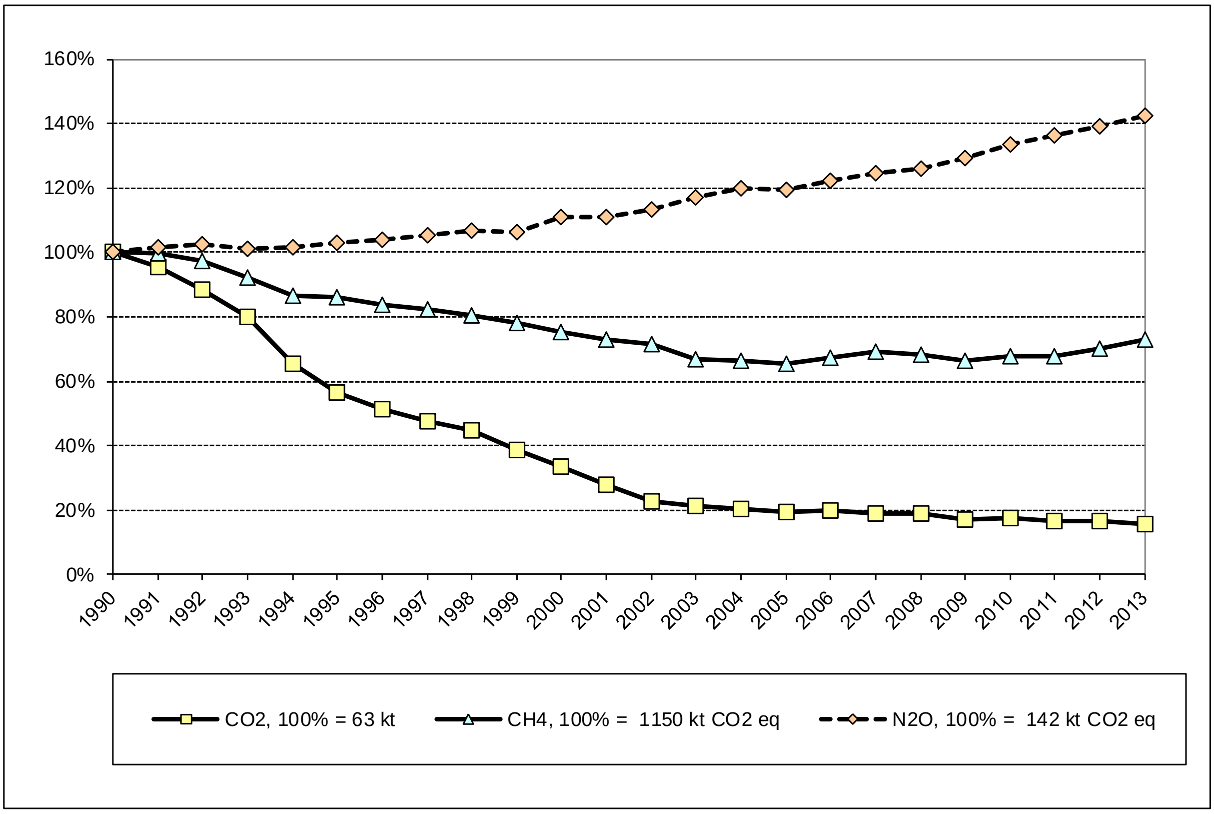


Figure 7-2 Trend of total GHG emissions from sector 5 Waste in Switzerland 1990–2013.

Box: Waste-related GHG emissions in Switzerland

Figure 7-3 provides an overview of all waste-related GHG emissions in Switzerland, which are reported in Chapter 7 and elsewhere in the NIR (see also Figure 7-4).

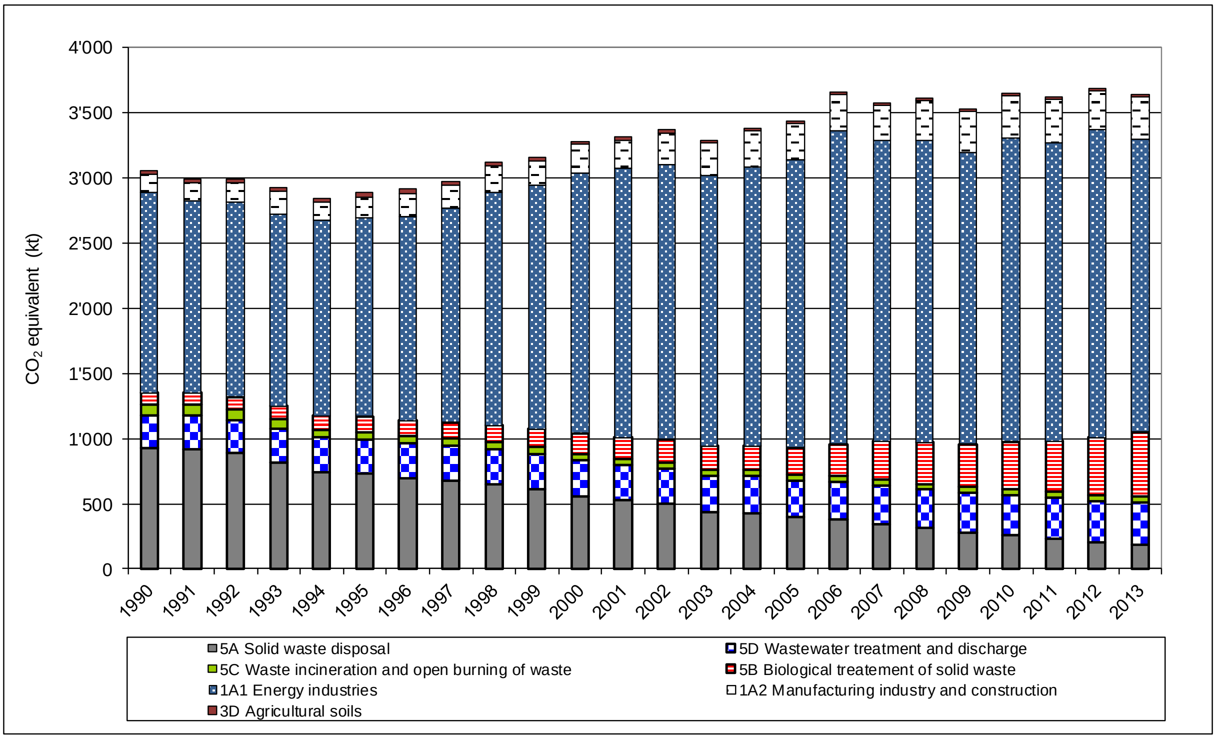


Figure 7-3 Total waste-related GHG emissions from 1990–2013, reported in different sectors.

7.1.2 Overview of Waste Management in Switzerland

The goals and principles regarding waste management in Switzerland are stated in the Guidelines on Swiss Waste Management (BUS 1986) and in the Waste Concept for Switzerland (SAEFL 1992). The four principles are:

- The generation of waste shall be avoided as far as possible.
- Pollutants from manufacturing processes and in products shall be reduced as far as possible.
- Waste shall be recycled wherever this is environmentally beneficial and economically feasible.
- Waste shall be treated in an environmentally sound way. In the long term only materials of final storage quality shall be disposed of in landfills.

Figure 7-4 gives a general overview of the type of treatment and amounts of waste fractions treated in the respective sectors in Switzerland in 2013, including imports and exports. Only waste fractions that are emission-relevant are shown. The figure furtherly illustrates where the processes related to the waste management system are reported in the NIR.

1 Energy: In accordance with the IPCC Guidelines (IPCC 2006) emissions from waste-to-energy activities, where waste is used as an alternative fuel for energy production, are reported in 1A Fuel Combustion Activities. This applies to Municipal Solid Waste Incineration Plants (MSWIP) and Special Waste Incineration Plants (SWIP), where energy is recovered, as well as to the cement industry, where special waste and sewage sludge are used as an alternative fuel. The digestion of biomass is also reported in sector 1 Energy, as biogas is used for co-generation of heat and electricity. The energy production from renewable goods, such as the use of waste wood in wood-fired power stations, is reported under 1A4ai and 1A4bi.

3 Agriculture: Since 2003 it is forbidden to use sewage sludge as a fertilizer. In 2013, within sector 3 Agriculture only compost used as fertilizer was emission–relevant (due to N_2O emissions as described in chapter 5.5.2.2, Table 5-18).

5 Waste: Only emissions from waste not used for energy production purposes are reported under sector 5 Waste. Solid waste disposal does not occur anymore in Switzerland as incineration is the mandatory disposal option for burnable waste since 2000. Emissions from composting are described under 5B1. Emissions related to the digestion not directly related to the energy production, such as the storage of digested biomass, are reported under 5B2. 5C Waste incineration accounts for a small fraction only, consisting of illegal waste incineration, sewage sludge incineration and burning of residues in agriculture and forestry. Special waste incineration without energy recovery, such as cable incineration or hospital waste incineration, no longer takes place and is thus crossed out in the figure. These waste fractions are also incinerated in MWSIP and therefore reported under sector 1 Energy. Emissions related to wastewater treatment are reported under 5D.

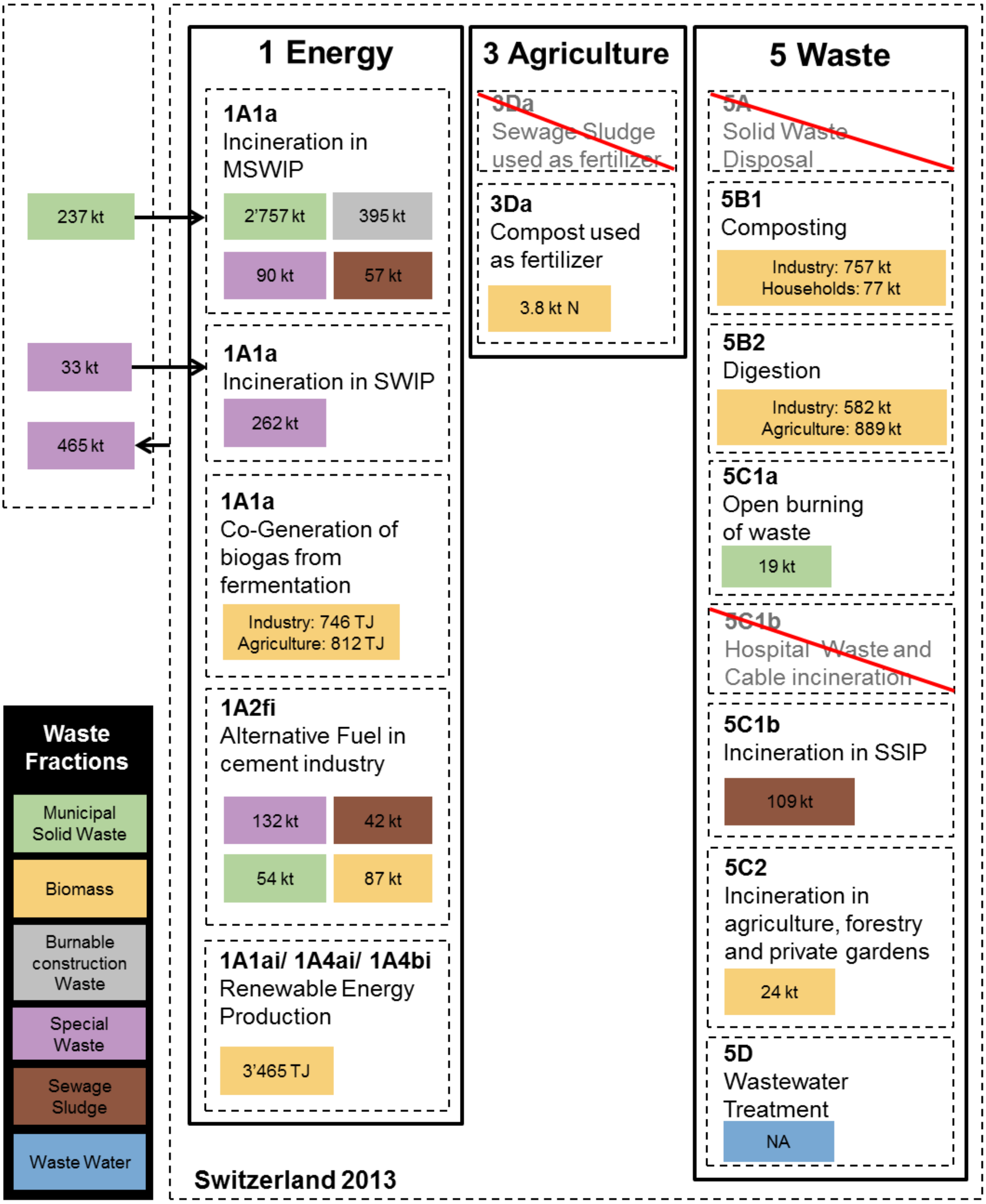


Figure 7-4 Overview on the type of treatment and amounts of waste fractions treated in the respective sectors in Switzerland in 2013. Abbreviations: MSWIP: Municipal Solid Waste Incineration Plant, SWIP: Special Waste Incineration Plant, SSIP: Sewage Sludge Incineration Plant.

Treatment and amounts of relevant waste fractions of Switzerland in 2013 (Figure 7-4, recycled amounts are not shown in the figure because they are not emission-relevant):

- **Municipal Solid Waste:** Switzerland has a very high recycling rate, 50% of the municipal solid waste is collected separately and recycled (FOEN 2013h). 2'757 kt MSW was incinerated in 2013. This number includes 237 kt MSW that were imported into Switzerland for incineration (mainly from neighbouring countries such as Germany, France, Austria and Italy). The import of waste into Switzerland needs to be authorized by the Federal Office for the Environment. A part of the separately collected plastic fractions from households and industry which cannot be recycled, is used as an alternative fuel in the cement industry (54 kt in 2013).

- **Construction Waste:** It is assumed that about 1.5 t construction waste is produced per inhabitant[12] per year. Thus, a total of about 12'100 kt construction waste was generated in Switzerland in 2013[13]. From this quantity 8’500 kt (about 70%) was recycled. About half of the recycling took place at the construction site, e.g. by reusing material left after breaking up the road cover. The other half was separated at the construction site and recycled individually, e.g. used glass, used metals, used concrete etc. (EMPA 2004a). A minor amount (of 395 kt), of burnable construction waste, was incinerated in MSWIP as shown in Figure 7-4 (internal numbers provided by the waste section of FOEN). The remaining, inert construction waste (about 3’200 kt) was disposed of in landfills for inert waste.
- **Special Waste:** Special waste refers to a highly diverse waste fraction containing hospital wastes, batteries, electronic waste, hazardous industrial sludge, contaminated soils, etc.). According to the yearly reported special waste statistics (FOEN 2014i) about 1’892 kt special waste was generated in Switzerland in 2012. About 353 kt special waste was recycled, 254 kt were biologically treated, 646 kt landfilled and approximately 465 kt exported for landfilling (FOEN 2014i). Only the amount of incinerated special waste is emission-relevant and shown in Figure 7-4. In 2013, 90 kt were incinerated in MWSIP (EMIS 2015/1 A 1 a_Kehrichtverbrennungsanlagen_20140123) and 262 kt in SWIP (EMIS 2015/1 A 1 a_Sondermüllverbrennungsanlagen 20140123). In 2013 132 kt special waste was used as an alternative fuel in the cement production (EMIS 2015/ 1 A 2 f i_Zementwerke Feuerung_20140123).
- **Sewage Sludge:** Since 2010 sewage sludge may not be used anymore as a fertilizer in agriculture due to the content of organic contaminants, heavy metals and other substances. 57 kt were incinerated in MSWIP, 109 kt were incinerated in SSIP without energy recovery (internal numbers provided by the waste section of FOEN) and 42 kt were used as an alternative fuel in the cement industry (EMIS 2015/ 1 A 2 f i_Zementwerke Feuerung).
- **Biomass:** The term biomass refers to a broad range of materials such as garden waste, grass, waste wood, liquid manure and production from the food industry or further fractions, depending on the process concerned. In 2013 24 kt residues from agriculture, forestry and private gardens were burned without energy recovery (EMIS 2015/5C2_Abfallverbrennung Land- und Forstwirtschaft). 1'558 kt biomass was digested and the amount of biomass composted in large-scale composting facilities (industrial composting) was 757 kt wet matter in 2013 plus 77 kt from household composting (EMIS 2015/1A1a/5B2 Fermentation of biogenic waste in industrial and trades biogas installations, and 1A1a/5B2 Fermentation in agricultural biogas installations). Quantities of biomass refer to the wet matter. 87 kt of biomass such as used wood or animal fat was used as an alternative fuel in the cement industry (EMIS 2015/ 1A2f i_Zementwerke Feuerung). Compost used as a fertilizer amounted to 3.8 kt N in 2013 (see Table 5-18 “other organic fertilisers”). 3’465 TJ wood was used for energy production purposes, for example in wood-fired power stations, chimneys, or pellet heating systems (SFOE 2014b).

[12] It is assumed that this estimation in FOEN 2010j still applies for the year 2013.

[13] Inhabitants in Switzerland in 2013: 8.089 million (SFSO 2014a).

7.2 Source Category 5A – Solid Waste Disposal

7.2.1 Source Category Description

Approach 1 key category 5A

CH_4 emissions from solid waste disposal (level and trend)

Approach 2 key category 5A

CH_4 emissions from solid waste disposal (level and trend)

The source category 5A1 Managed waste disposal sites comprises all emissions from managed solid waste landfill sites.

As incineration is mandatory to dispose burnable waste since 2000, inputs into managed solid waste landfill sites have dropped to zero. Emissions thus stem from landfilling before 2000. Emissions from the source category 5A2 Unmanaged Waste Disposal Sites are included in source category 5A1 Managed Waste Disposal Sites. This is motivated by the fact that in Switzerland no official unmanaged waste disposal sites exist. Although no reliable data is available, the effective quantity of waste not properly treated in landfills is estimated to be very small.

In Switzerland, six managed biogenic active landfills were equipped to recover landfill gas in 2013 (SFOE 2014a). While some landfill gas is used to generate heat only, the landfill gas is generally used in co-generation plants in order to produce electricity and heat. A very small amount of the landfill gas is flared.

Table 7-2 Specification of source category 5A Solid Waste Disposal. EMIS 2015/… refers to the internal documentation of the emission database and contains further references regarding specific AD and/or EF.

5A	Source	Specification	Data Source
5A1	Managed Waste Disposal Sites	Emissions from managed solid waste landfill sites.	EMIS 2015/1A1a & 5A1 Kehrichtdeponien
5A2	Unmanaged Waste Disposal Sites	Officially no unmanaged waste disposal sites exist (included in 5A1)	
5A3	Uncategorized Waste Disposal Sites	Not ocurring in Switzerland	

7.2.2 Methodological Issues

The emissions are calculated in four steps:

i) The rate of CH_4 generation over time is based on the First Order Decay model (FOD) according to IPCC (IPCC 1997a-c). The following equation is applied to calculate the CH_4 generation in the year t:

$$CH_4 \text{ generated in the year t [kt/year]} = \sum_x [A \cdot k \cdot M(x) \cdot L_0(x) \cdot e^{-k(t-x)}] \cdot (1-OX)$$

where

t = current year

x = the year of waste input, $x \leq t$

A = (1-k)/k, norm factor (fraction)

k = methane generation rate [1/yr]

M(x) = the amount of waste disposed in year x

$L_0(x)$ = methane generation potential (MCF(x) • DOC(x) • DOCF • F • 16/12) [kt CH_4 / kt waste]

MCF(x) = methane correction factor (fraction)

DOC(x) = degradable organic carbon [kt C/ kt waste]

DOCF = portion of DOC, that is converted to landfill gas (fraction)

F = portion of CH_4 in landfill gas (fraction)

16/12 = factor to convert C to CH_4.

OX = oxidation factor (fraction)

The following general assumptions are made:

MCF(x) = constant = 1 (default value according to IPCC for managed solid waste disposal sites)

OX = 0.1 (default value according to IPCC 1997b-c)

DOCF = 0.6 (default value according to IPCC 1997b-c)

F = 0.5 (default value according to IPCC 1997b-c)

The degradable organic carbon DOC(x) is calculated based on country-specific waste composition for municipal solid waste, construction waste and sewage sludge and default values for DOC(x) adopted from IPCC (1997b), table 6-3. Assumptions for the composition are summarized in Table 7-3.

Table 7-3 Composition of landfilled Municipal Solid Waste (MSW), Construction Waste (CW) and Sewage Sludge (SS) used to derive DOC (EMIS 2015/1A1 a / 5A Kehrichtdeponien). Years between 1993 and 2003 are linearly interpolated.

Fraction IPCC	**MSW**		**CW**		**SS**	
	1993	**2003**	**1993**	**2003**	**1993**	**2003**
	%	%	%	%	%	%
Paper, textiles and cardboard	28	20	0	0	0	0
Garden waste and non-food organic putrescible	5	2	0	0	100	100
Food waste	22	27	0	0	0	0
Wood and straw	0	0	67	67	0	0
Other (glass, metals, plastics, minerals, etc. do not contribute to methane generation)	45	51	33	33	0	0
Sum	100	100	100	100	100	100

The methane generation rate k is based on expert judgement taking into account the country-specific conditions as well as the type of waste disposed of in landfills (EMIS 2015/1A1a & 5A Kehrichtdeponien).

The parameters shown in Table 7-4 are applied for the calculation of CH_4 generated, distinguishing the following three categories of waste: Municipal solid waste, construction waste, and sewage sludge.

Table 7-4 Parameters used for First Order Decay (FOD) model.

waste category	**k [yr^{-1}]**	**L_0 [kt CH_4 / kt waste]**	**resulting DOC [-]**
municipal solid waste	0.139	0.050	1990-1992: 0.15 1993-2002: linear interpolation 2003-2012: 0.12
construction waste	0.046	0.080	0.20
sewage sludge	0.069	0.068	0.17

ii) In a second step, the amount of CH_4 that is recovered and used as fuel for co-generation units or flared is subtracted from the CH_4 generated in landfills (resulting from step 1).

$$CH_4\ emissions_{step\ ii} = CH_4\ emissions_{step\ i} - (CH_4\ emissions_{step\ i}) * Fl(t)) - Qco\text{-}gen(t)$$

where

Fl(t) = portion of generated methane that is flared in the year t (fraction)

Qco-gen(t) = Amount of CH_4 that is recovered in co-generation units in the year t (kt)

iii) In the third step CH_4 emissions from on-site open burning are added. This results in the overall CH_4 emissions from landfill sites.

$$CH_4\ emissions_{step\ iii} = CH_4\ emissions_{step\ ii} + Qopen(t)$$

where

Qopen(t) = CH_4 which is emitted from open burning in the year t (kt)

iv) In the fourth and last step the emissions of the other gases are calculated. The respective emissions are considered as proportional to the amount of CH_4 burnt (co-generation and flaring) or to the amount of waste burnt (open burning).

Emission Factors

Emission factors for CO_2, CH_4, CO, NMVOC and SO_2 are country-specific based on measurements and expert estimates, as documented in EMIS 2015/1A1 & 5A Kehrichtdeponien. CO_2 emissions from non-biogenic waste are included, while the CO_2 emissions from biogenic waste are excluded from total emissions. Table 7-5 presents the emission factors used in 5A1.

Table 7-5 Emission Factors for 5A1 Managed waste disposal sites in 2013.

5A1 Managed waste disposal sites	CO_2 biogen	CO_2 fossil	CH_4	NO_x	CO	NMVOC	SO_2
	t / t CH_4 produced						
Direct emissions from landfill	3.00	0	1				
	kg / t CH_4 burned						
Flaring	2750	0		1	17		
	kg / t waste burned						
Open burning	553	506	6	2.5	50	16	0.8

Activity Data

There are two kinds of activity data for 5A1 Managed waste disposal sites: Waste quantities and CH_4 direct emissions. Waste quantities disposed on landfills and the municipal solid waste burnt on-site (source EMIS 2015/1A1a & 5A Kehrichtdeponien) are shown in Table 7-6, CH_4 direct emissions in Table 7-7.

Table 7-6 Activity data in 5A1: Waste disposed on managed waste disposal sites from 1990 to 2013 (source EMIS 2015/1A1a & 5A Kehrichtdeponien).

5A1 Managed waste disposal sites	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Municipal solid waste (MSW)	kt	637.0	637.0	637.0	637.0	581.2	531.9	482.7	472.8	463.0	465.3
Construction waste	kt	147.0	170.5	170.5	123.5	59.1	47.3	35.5	35.5	41.4	41.6
Sewage sludge	kt (dry)	58.8	58.8	58.8	48.8	39.0	27.7	16.3	12.2	8.1	6.1
Open burned waste	kt	17.2	20.0	20.0	18.2	10.9	9.7	8.5	8.3	8.2	5.5
Total waste quantity	kt	860.0	886.3	886.3	827.5	690.2	616.6	542.9	528.7	520.6	518.5

5A1 Managed waste disposal sites	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Municipal solid waste (MSW)	kt	288.8	184.8	80.8	52.2	23.7	13.6	3.5	1.5	1.2	0.0
Construction waste	kt	30.7	17.7	4.8	3.4	2.0	1.4	0.8	0.0	0.0	0.0
Sewage sludge	kt (dry)	4.1	3.9	3.6	2.6	1.6	1.0	0.3	0.0	0.0	0.0
Open burned waste	kt	3.5	2.2	0.9	0.6	0.1	0.1	0.0	0.0	0.0	0.0
Total waste quantity	kt	327.0	208.6	90.1	58.8	27.5	16.1	4.7	1.5	1.2	0.0

5A1 Managed waste disposal sites	Unit	2010	2011	2012	2013
Municipal solid waste (MSW)	kt	0.0	0.0	0.0	0.0
Construction waste	kt	0.0	0.0	0.0	0.0
Sewage sludge	kt (dry)	0.0	0.0	0.0	0.0
Open burned waste	kt	0.0	0.0	0.0	0.0
Total waste quantity	kt	0.0	0.0	0.0	0.0

Table 7-6 documents the amounts of municipal solid waste, construction waste, sewage sludge and open burnt waste disposed of on managed waste disposal sites over the time period 1990–2013.

The continuous decline happened due to changes in the legislative framework, making incineration the mandatory disposal option for burnable waste and banning its disposal on landfills from 1 January 2000. The amounts of burnable waste disposed of on managed waste disposal sites reached zero in 2009.

The second kind of activity data for 5A1 Managed waste disposal sites are CH_4 direct emissions and CH_4 flared (Table 7-7). The landfill gas recovered and used as fuel for co-generation units is reported under 1A1 Energy in accordance with the 2006 IPCC Guidelines (IPCC 2006). The sum of landfill gas flared and landfill gas used in co-generation units is reported as being recovered in CRF-table 5.A.

Table 7-7 Activity data in 5A1: CH_4 direct emissions and CH_4 flared from 1990 to 2013 (source EMIS 2015/1A1a & 5A Kehrichtdeponien).

5A1 Managed waste disposal sites	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4 direct emissions	kt	36.8	36.5	35.1	32.5	29.6	29.1	27.8	27.1	25.9	24.6
CH_4 flared	kt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CH_4 used in co-generation units (reported under 1A1a)	kt	4.9	5.7	7.6	10.4	12.6	12.1	12.1	11.5	11.3	11.4

5A1 Managed waste disposal sites	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CH4 direct emissions	kt	22.4	21.1	20.0	17.6	17.3	16.1	15.3	14.0	12.6	11.4
CH4 flared	kt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CH4 used in co-generation units (reported under 1A1a)	kt	11.3	10.0	8.1	7.7	5.3	4.1	2.7	2.1	1.8	1.5

5A1 Managed waste disposal sites	Unit	2010	2011	2012	2013
CH4 direct emissions	kt	10.6	9.5	8.5	7.7
CH4 flared	kt	0.0	0.0	0.0	0.0
CH4 used in co-generation units (reported under 1A1a)	kt	1.0	0.9	0.9	0.8

The CH_4 generated in landfills decreased since 1990 because waste quantities disposed of in landfills have been decreasing. Together with the relative increase of CH_4 recovery from 1990 until 2013 this is the reason for CH_4 emissions from the source category 5A being a key source regarding trend.

7.2.3 Uncertainties and Time-Series Consistency

Uncertainty in CH_4 and CO_2 emissions from 5A Solid waste disposal

For the activity data, i.e. amount of waste disposed of in landfills, the IPCC default value for countries with high-quality data (weighing at all SWDS) is adequate for Switzerland: 10% (IPCC 2006, chp. 3, table 3.5).

An uncertainty of 50% is assumed for the CH_4 emission factor (EMIS 2015/1A1a & 5A Kehrichtdeponien). These assumptions lead to a combined uncertainty of the direct CH_4 emissions of 51%.

For CO_2 emitted by flaring no uncertainty are considered since there is no flaring reported in the current submission.

Consistency: Time series for 5A Solid waste disposal are all considered consistent.

7.2.4 Source-Specific QA/QC and Verification

The general QA/QC measures are described in section 1.2.3.

7.2.5 Source-Specific Recalculations

Due to the recalculation of the C-content of municipal solid waste and the changes in the shares of fossil C in waste (see recalculations in 1A1a Public Electricity and Heat Production), the EF for open burning on solid waste disposal sites is assumed to have changed accordingly.

As an outcome of the UNFCCC review of the inventory of the year 2014 Switzerland had to set the AD of biogas flared to zero (1990–2013) until there is a better estimate of the amount of gas flared on Swiss disposal sites.

7.2.6 Source-Specific Planned Improvements

There are no source-specific planned improvements for the source category 5A Solid waste disposal except of a better estimate of the amount of gas flared as mentioned above.

7.3 Source Category 5B – Biological Treatment of Solid Waste

7.3.1 Source Category Description

Approach 1 Key category 5B

CH_4 from biological treatment of solid waste (level and trend)

Approach 2 Key Category 5B

CH_4 from biological treatment of solid waste (level and trend)

The source category 5B Biological treatment of solid waste comprises the process related GHG emissions from composting and from digesting of organic waste.

Within the source category 5B1 Composting four types of composting means are distinguished, namely i) hall composting, ii) field edge composting, iii) box composting, and iv) windrow composting. Composting covers the GHG emissions from centralized composting plants with a capacity of more than 100 tons of organic matter per year. Backyard composting is also common practice in Switzerland. It is assumed that the quantities treated in small composting facilities such as gardens, backyards etc., add up to

10% of those treated in industrial composting plants (EMIS 2015/5B1 Kompostierung Industrie).

In 5B2 Anaerobic digestion at biogas facilities the digested matter (solid left-overs after completion of anaerobic microbial degradation of organic matter) is being composted. The biogas is used for combined heat and power generation or upgraded and used as fuel.

In 5B Biological treatment of solid waste the emissions from the composting of the digested matter as well as the methane losses resulting from biogas upgrading are included. The emissions related to the use of biogas in co-generation plants and emissions from biogas-upgrading are reported under the sector 1 Energy.

Table 7-8 Specification of source category 5B Biological Treatment of Solid Waste. "EMIS 2015/…" refers to the internal documentation of the emission database and contains further references regarding specific AD and/or EF.

5B	Source	Specification	Data Source
5B1	Composting	Process related emissions from composting of organic waste	AD, EF: EMIS 2015/5B1 Kompostierung Industrie
5B2	Anaerobic digestion at biogas facilities	Process related emissions from digesting of organic waste	AD, EF: EMIS 2015/5B2 Biogasauf-bereitung, EMIS 2015/1A1a und 5B2 Vergärung IG, EMIS 2015/1A1a und 5B2 Vergärung LW

7.3.2 Methodological Issues

Methodology

For the emissions from 5B1 Composting a country-specific method is used. The GHG emissions are calculated by multiplying the quantity of waste by the emission factors. For all years, the same constant emission factors have been applied.

For the emissions from 5B2 Anaerobic digestion at biogas facilities, a country-specific method is used as well. Digestion plants lead to GHG emissions from the storage of fermentable waste, losses due to leakages and diffusion, power water (storage of liquid fermented waste), rotting (storage of solid fermented waste) and flaring. The GHG emissions are calculated by multiplying the quantity of digested waste by the emission factors. For all years, constant emission factors have been applied, except for CH_4. The CH_4 emissions from biogas upgrading are calculated by multiplying the amount of upgraded biogas by the percentage of CH_4 losses.

Because of the increase in composting and digesting organic waste the source category 5B Biological treatment of solid waste is a key source regarding level and trend.

Emission Factors

Emission factors for composting and digestion are country-specific based on measurements and expert estimates, documented in different internal documentations of the emission database:

- EMIS 2015/5B1 Kompostierung Industrie

- EMIS 2015/5B2 Biogasaufbereitung
- EMIS 2015/1A1a und 5B2 Vergärung IG
- EMIS 2015/1A1a und 5B2 Vergärung LW

Table 7-9 presents the emission factors used in 5B. The digestion process is split into different activities for industrial and agricultural biogas plants including: storage of fermentable waste, losses due to leakages and diffusion, power water (storage of liquid fermented waste), rotting (storage of solid fermented waste) and flaring. For agricultural plants, reliable data on the emission factors exist for the storage of fermentable waste and the storage of the liquid fermented waste. For the purposes of a very rough initial estimate, the emission factors given here are taken from the corresponding sub-processes of the industrial and trades biogas installations. For each activity, new AD and EF have been reported, based on the newest data available.

CH_4 emissions from biogas–upgrading occur due to leakage and are assumed to be 5% of the total biogas production (value for 1990–2013).

Emissions from composting encompass CO_2, CH_4, NH_3, N_2O and NMVOC and are based on measured or estimated values reported in the literature. CH_4 emission factors are taken from SFOE (1999), N_2O emission factors from Schenk (1997) and SFOE (1999).

Table 7-9 Emission factors for 5B Biological treatment of solid waste in 2013.

5B Biological treatment of solid waste	Unit	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Composting	g/t composted waste	5'000	70			1'700	
Digestion (industrial, storage)	g/t digested waste	92	12			70	
Digestion (industrial, losses)	g/t biogas losses	426'903					
Digestion (industrial, power water)	g/t digested waste (liquid)	1'845	2			400	
Digestion (industrial, rotting)	g/t digested waste (solid)	1'014	98			230	
Digestion (industrial, flaring)	g/t CH4	41		4'066	2'054	82	616
Digestion (agricultural, losses)	g/t biogas losses	426'903					
Digestion (agricultural, power water)	g/t digested waste (liquid)	16'392	2			400	
Digestion (agricultural, rotting)	g/t digested waste (solid)	1'100	98			230	
Digestion (agricultural, flaring)	g/t CH4	246		4'066	2'054	82	616
Biogas up-grade	g/GJ	1'075					

Activity Data

Activity data for composting are documented in EMIS 2015/5B1 Kompostierung Industrie. The data are based on periodically collected reliable statistical data, with the latest available data from the year 2007. Since then values have been extrapolated. The quantities for backyard composting are estimated as constant shares of industrial composting, i.e. 10% of the amount of waste from industrial composting plants.

Activity data for digestion are taken from the Swiss renewable energy statistics (SFOE 2014a) and encompass amounts of biogas produced and the number of biogas facilities. From these values a model is used to calculate activity data of all relevant sub-processes, e.g. storage of fermentable waste, losses due to leakages and diffusion, power water (storage of liquid fermented waste), rotting (storage of solid fermented waste) and flaring.

The biogas used as fuel for co-generation units is reported under 1A1 Energy in accordance with the 2006 IPCC Guidelines (IPCC 2006).

Table 7-10 Activity data in 5B Biological treatment of solid waste.

5B Biological treatment of solid waste	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Composting	kt	260	300	320	350	370	400	450	480	500	510
Digestion (ind., storage, digestable waste)	kt	0	0	9	9	17	27	26	33	40	56
Digestion (ind., losses, biogas)	kt	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.04	0.05	0.07
Digestion (ind., power water, digested waste liquid)	kt	0	0	5	5	10	15	15	18	22	31
Digestion (ind., rotting, digested waste solid)	kt	0	0	3	3	6	9	9	11	14	19
Digestion (ind., flaring, CH_4)	kt	0.00	0.00	0.01	0.01	0.02	0.03	0.05	0.06	0.08	0.10
Digestion (agr., losses, biogas)	kt	0.28	0.28	0.27	0.26	0.25	0.23	0.22	0.21	0.22	0.25
Digestion (agr., power water, digested waste liquid)	kt	113	112	110	103	100	94	92	87	91	103
Digestion (agr., rotting, digested waste solid)	kt	6	6	6	5	5	5	5	5	5	5
Digestion (agr., flaring, CH_4)	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biogas up-grade	GJ	0	0	0	0	0	0	0	3'053	5'684	8'526

5B Biological treatment of solid waste	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Composting	kt	640	650	730	732	733	735	737	739	742	746
Digestion (ind., storage, digestable waste)	kt	60	74	83	82	90	107	137	163	176	224
Digestion (ind., losses, biogas)	kt	0.07	0.09	0.10	0.10	0.10	0.13	0.16	0.19	0.20	0.25
Digestion (ind., power water, digested waste liquid)	kt	33	41	46	46	50	60	76	91	98	125
Digestion (ind., rotting, digested waste solid)	kt	20	25	28	28	31	37	47	56	60	77
Digestion (ind., flaring, CH_4)	kt	0.10	0.12	0.15	0.14	0.15	0.17	0.23	0.27	0.30	0.39
Digestion (agr., losses, biogas)	kt	0.30	0.33	0.36	0.40	0.47	0.62	0.80	1.01	0.92	0.74
Digestion (agr., power water, digested waste liquid)	kt	125	123	127	136	144	181	261	383	436	463
Digestion (agr., rotting, digested waste solid)	kt	7	7	7	7	8	10	14	20	23	24
Digestion (agr., flaring, CH_4)	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biogas up-grade	GJ	20'084	25'768	20'842	23'116	33'347	41'305	42'442	51'916	73'137	86'779

5B Biological treatment of solid waste	Unit	2010	2011	2012	2013
Composting	kt	750	753	757	760
Digestion (ind., storage, digestable waste)	kt	307	392	527	582
Digestion (ind., losses, biogas)	kt	0.34	0.43	0.57	0.62
Digestion (ind., power water, digested waste liquid)	kt	171	218	293	324
Digestion (ind., rotting, digested waste solid)	kt	105	134	180	199
Digestion (ind., flaring, CH_4)	kt	0.52	0.64	0.84	0.91
Digestion (agr., losses, biogas)	kt	0.57	0.62	0.72	0.84
Digestion (agr., power water, digested waste liquid)	kt	541	583	686	800
Digestion (agr., rotting, digested waste solid)	kt	29	31	36	42
Digestion (agr., flaring, CH_4)	kt	0.12	0.13	0.16	0.20
Biogas up-grade	GJ	124'295	172'042	241'768	290'653

To improve transparency the CH_4 and N_2O emissions of sector 5B Biological treatment of solid waste are shown on a completely disaggregated level in Table 7-11.

Table 7-11 CH_4 and N_2O emissions of 5B Biological treatment of solid waste.

5B Biological treatment of solid waste	Gas	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Composting	CH_4	t	1300	1500	1600	1750	1850	2000	2250	2400	2500	2550
	N_2O	t	18.2	21.0	22.4	24.5	25.9	28.0	31.5	33.6	35.0	35.7
Digestion (industrial)	CH_4	t	0	0	225	221	432	692	581	620	636	704
	N_2O	t	0.0	0.0	0.4	0.4	0.8	1.3	1.2	1.5	1.9	2.6
Digestion (agricultural)	CH_4	t	1973	1954	1931	1810	1747	1637	1613	1519	1589	1791
	N_2O	t	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.6	0.7	0.7
Biogas up-grade	CH_4	t	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	6.1	9.2

5B Biological treatment of solid waste	Gas	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Composting	CH_4	t	3200	3250	3650	3659	3667	3676	3685	3693	3712	3730
	N_2O	t	44.8	45.5	51.1	51.2	51.3	51.5	51.6	51.7	52.0	52.2
Digestion (industrial)	CH_4	t	563	627	628	543	510	511	576	598	553	584
	N_2O	t	2.8	3.4	3.9	3.8	4.2	5.0	6.4	7.6	8.2	10.4
Digestion (agricultural)	CH_4	t	2176	2164	2248	2409	2576	3248	4640	6730	7572	7928
	N_2O	t	0.9	0.9	0.9	1.0	1.0	1.3	1.9	2.7	3.1	3.3
Biogas up-grade	CH_4	t	21.6	27.7	22.4	24.8	35.8	44.4	45.6	55.8	78.6	93.3

5B Biological treatment of solid waste	Gas	Unit	2010	2011	2012	2013
Composting	CH_4	t	3748	3766	3784	3802
	N_2O	t	52.5	52.7	53.0	53.2
Digestion (industrial)	CH_4	t	633	790	1037	1119
	N_2O	t	14.3	18.3	24.5	27.1
Digestion (agricultural)	CH_4	t	9138	9853	11589	13512
	N_2O	t	3.9	4.2	4.9	5.7
Biogas up-grade	CH_4	t	133.6	184.9	259.9	312.5

7.3.3 Uncertainties and Time-Series Consistency

Uncertainty in CH_4 emissions from composting and digestion

The uncertainty of the CH_4 emission factors in category 5B1 from composting of organic waste is estimated to be 40% (EMIS 2015/5B1 Kompostierung Industrie). The contribution of 5B1 to the CH_4 emissions of 5B is about 75%. For 5B2 the same uncertainty is assumed.

The uncertainty of the related activity data is estimated to be 10% (EMIS 2015/5B1 Kompostierung Industrie) due to a high reliability of the waste statistics.

The uncertainty of the N_2O emission factor is unknown. Therefore, the uncertainty of N_2O emissions is estimated to be medium, which is attributed by Table 1-11 to a combined uncertainty of 80%.

Consistency: Time series for 5B Biological treatment of solid waste are all considered consistent.

7.3.4 Source-Specific QA/QC and Verification

The general QA/QC measures are described in section 1.2.3.

7.3.5 Source-Specific Recalculations

Values of the amounts of biogas used and fed into the gas system have changed for the years 2011 and 2012 in the Swiss renewable energy statistics (2014a). This leads to changes in activity data of industrial biogas facilities.

The amount of digestate used by agricultural biogas facilities has been corrected due to a plausibility check based on detailed data provided by Ökostrom Switzerland (Oekostrom 2014) and FOEN monitoring reports for CO_2 compensation projects. This leads to changes in the activity data of industrial biogas facilities.

7.3.6 Source-Specific Planned Improvements

There are no source-specific planned improvements in this category.

7.4 Source Category 5C – Incineration and Open Burning of Waste

7.4.1 Source Category Description

Source category 5C Waste Incineration is **not a key category**.

There is a long tradition in Switzerland to incinerate waste. The heat generated during the incineration has to be recovered if technically and economically feasible. In accordance with the 2006 IPCC Guidelines (IPCC 2006) emissions from the combustion of waste-to-energy activities are dealt with in 1A Fuel Combustion Activities.

5C1 contains incineration of hospital wastes, illegal waste incineration, incineration of insulation of materials from cables, of sewage sludge and of crematoria.

5C2 consists of emissions from open burning of branches in agriculture, forestry and gardening. Field burning of agricultural residues does not occur in Switzerland.

Table 7-12 Overview of waste incineration sources reported under 5C. "EMIS 2015/…" refers to the internal documentation of the emission database and contains further references regarding specific AD and/or EF.

5C	Waste incineration	Specification	Data Source
5C1	Hospital waste incineration	Emissions from incinerating hospital waste in hospital incinerators	AD, EF: EMIS 2015/5C1 Spitalabfall-Verbrennung
	Illegal waste incineration	Emissions from illegal incineration of municipal solid wastes at home. Emissions from waste incineration at construction sites (open burning)	AD, EF: EMIS 2015/5C1Abfallverbrennung illegal
	Insulation material from cables	Emissions from incinerating cable insulation materials	AD, EF: EMIS 2015/5C1 Kabelabbrand
	Sewage sludge	Emissions from sewage sludge incineration plants	AD, EF: EMIS 2015/5C1 Klärschlamm-Verbrennung
	Crematoria	Emissions from the burning of bodies in crematoria	AD, EF: EMIS 2015/5C1 Krematorien
5C2	Open burning of branches	Open burning of branches in agriculture, forestry and gardening.	AD, EF: EMIS 2015/5C2 Abfallverbrennung in der Land- und Forstwirtschaft

7.4.2 Methodological Issues

Methodology

For the calculation of the GHG emissions a country-specific Tier 2 method is used. In general, the GHG emissions are calculated by multiplying the waste quantity incinerated by emission factors. For crematoria, the GHG emissions are calculated by multiplying the number of cremations by emission factors.

For sewage sludge incineration plants the respective waste quantities are based on reliable statistical data (updated every two years until 2006). The emission factors are based on emission declarations from an incineration plant in 2002 that covered approximately one third of the Swiss capacities. Due to the lack of better or newer data these EF are kept constant since then and no improvement in flue gas cleaning standards is assumed.

For hospital waste incineration, illegal waste incineration and incineration of insulation material, the waste quantities used are based on expert estimates.

The emissions of burning of residues in agriculture and forestry are calculated by multiplying the annual estimate of branches burned (in kt of wood equivalent) by emission factors (IPCC default method).

Emission Factors

Emission factors of all categories under 5C1 for CO_2, CH_4, N_2O, CO, NMVOC and SO_2 are country-specific based on measurements and expert estimates, as documented in the EMIS 2015/5C1 database. Table 7-13 presents an overview of the emission factors 2013 used in 5C:

Table 7-13 Emission factors for 5C Waste incineration and open burning of waste in 2013. Sources; EMIS 2015/5C1 and EMIS 2015/5C2 (details see Table 7-12), EMEP/EEA (2013).

5C Waste incineration and open burning of waste	**CO_2** t/t	**CH_4** kg/t	**N_2O** g/t	**NO_x** kg/t	**CO** kg/t	**NMVOC** kg/t	**SO_2** kg/t
Clinical waste incineration	0.9	0	60	1.5	1.4	0.3	1.3
Municipal waste incineration (illegal)	0.51	6	150	2.5	50.0	16	0.75
Industrial waste incineration	1.3	0	0	1.3	2.5	0.5	6
Sewage sludge incineration	0	0.10	800	0.7	0.19	0.0050	0.47
Open burning of natural residues in agriculture	NA	6.8	180	1.38	48.8	1.5	0.03
Open burning of natural residues in forestry	NA	6.8	180	1.38	48.8	1.5	0.03
Open burning of natural residues in private households	NA	6.8	180	1.38	48.8	1.5	0.03
	CO_2 t/crem.	**CH_4** kg/crem.	**N_2O** g/crem.	**NO_x** kg/crem.	**CO** kg/crem.	**NMVOC** kg/crem.	**SO_2** kg/crem.
Cremation	NA	0	0	0.21	0.14	0.012	0

Comments to the CO_2 emission factors:

- For all waste incineration categories, only CO_2 emissions from non-biodegradable waste are taken into account.
- Hospital waste incineration plants: The waste is mainly of fossil origin. The default value for the CO_2 emission factor is taken from SAEFL (2000). Since 2002, no emissions from hospital waste incineration occur, as all special hospital waste incinerator plants have been closed and hospital waste is incinerated in municipal solid waste incineration plants (accounted for in 1A1).
- Illegal waste incineration: The CO_2 emission factor is estimated by using the same assumption as in case of MSW incineration: The C-content is based on the study FOEN (2014l) and the fossil fraction of C was determined by Rytec (2014). See also chapter 3.2.5.2. Detailed information is given in EMIS 2015/1A1a Kehrichtverbrennungsanlagen (pp. 5-7)
- Insulation materials: The CO_2 emission factor is based on measurements of the flue gas treatment of a cable disassembling site where O_2 was measured in the flue gas. Assuming that the ratio of CO_2/O_2 is the same as in municipal solid waste incineration plants, a fraction of 7% of CO_2 results. Based on these assumptions, an EF of 1.3 kg/kg cable can be derived. Since 1995, no emissions from incinerating cable insulation materials occurred.
- Sewage sludge plants: Sewage sludge is biodegradable waste. The emission factor for CO_2 is 0. It is assumed that the share of fossil fuel used during the start-ups is negligible.

Additional information on emission factors of all other (non-CO_2) gases:

- Hospital: All emission factors are taken from SAEFL (2000).
- Illegal waste incineration: The emission factor for N_2O is taken from the 2006 IPCC Guidelines (IPCC 2006, vol. Waste), the emission factors for CH_4, SO_2, NO_x, NMVOC from SAEFL (2000) and USEPA (1995a).
- Insulation materials: All emission factors are adopted from SAEFL (2000).
- Sewage sludge plants: For 1990 emission factors are taken from SAEFL (2000). From 2002 onwards constant emissions factors are used, which are deduced from measurements (LHA 2004) taken at the largest sewage sludge incineration plant

incinerating one third of Switzerland’s sewage sludge. Between 1990 and 2002 the emission factors are interpolated. They show reductions in NMVOC, CO, SO_2 and CH_4 emissions due to gradual technical improvements.

- Crematoria: NMVOC and CO emissions were reduced by technical improvements. A large number of measurements has been analysed (crematoria as well as other types of installations are obliged to monitor their emissions by the Swiss Federal Ordinance on Air Pollution Control (Swiss Confederation 1985)) such that plant-specific emission factors are available. The emission factors are prepared as weighted averages of several technical levels of flue gas treatment. The emission factors of 2011 were calculated by linearly extrapolating estimations for 2008 by taking into account an increase in the number of technically improved crematoria (EMIS 2015/5C1 Krematorien).
- The emission factors of burning of branches in agriculture and forestry are calculated based on EMEP/EEA (2013) except for CH_4 und N_2O which are based on EMEP/CORINAIR (EMEP/EEA 2002) and EMIS 2015/5C2 Abfallverbrennung in der Land- und Forstwirtschaft.
- General remark: In years with no specific data for activity data or emission factors the respective data are interpolated.

Activity Data

The activity data for 5C Waste Incineration are the quantities of waste incinerated, see Table 7-14.

Table 7-14 Activity data for the different emission sources within source category 5C Waste incineration and open burning of waste.

5C Incineration and open burning of waste	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Clinical waste incineration	kt	30.0	27.5	25.0	22.5	20.0	17.5	15.0	12.5	10.0	7.5
Municipal waste incineration (illegal)	kt	32.3	31.7	31.0	29.7	27.3	26.2	25.0	24.6	24.2	25.1
Industrial waste incineration	kt	7.5	6.0	4.5	3.0	1.5	0.0	0.0	0.0	0.0	0.0
Sewage sludge incineration	kt dry	57.0	53.9	50.7	47.6	44.4	50.2	56.0	59.6	63.2	63.8
Open burning of natural residues in agriculture	kt	16.5	16.2	16.0	15.7	15.5	15.2	15.0	14.7	14.5	14.2
Open burning of natural residues in forestry	kt	28.8	28.0	27.1	26.2	25.4	24.5	23.6	22.8	21.9	21.0
Open burning of natural residues in private households	kt	6.1	5.8	5.6	5.3	5.1	4.9	4.6	4.4	4.1	3.9
Total	kt	178.2	169.1	159.9	150.1	139.1	138.5	139.2	138.6	137.9	135.5
Cremation	Numb.	37'513	37'407	37'939	38'884	39'620	40'968	41'932	43'468	43'456	44'180

5C Incineration and open burning of waste	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Clinical waste incineration	kt	5.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Municipal waste incineration (illegal)	kt	24.9	24.1	23.8	22.9	22.3	21.7	22.6	22.1	22.4	20.7
Industrial waste incineration	kt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sewage sludge incineration	kt dry	64.3	70.2	76.0	86.5	97.0	94.9	92.7	95.2	97.7	100.1
Open burning of natural residues in agriculture	kt	14.0	13.8	13.5	13.3	13.0	12.8	12.5	12.3	12.0	11.8
Open burning of natural residues in forestry	kt	20.2	19.3	18.4	17.6	16.7	15.9	15.0	14.1	13.3	12.4
Open burning of natural residues in private households	kt	3.6	3.4	3.2	2.9	2.7	2.4	2.2	1.9	1.7	1.5
Total	kt	132.0	133.2	134.9	143.2	151.7	147.6	145.0	145.6	147.1	146.5
Cremation	Numb.	44'821	45'681	45'979	47'488	46'128	48'169	48'083	49'413	51'116	52'402

5C Incineration and open burning of waste	Unit	2010	2011	2012	2013
Clinical waste incineration	kt	0.0	0.0	0.0	0.0
Municipal waste incineration (illegal)	kt	21.0	20.3	20.3	19.4
Industrial waste incineration	kt	0.0	0.0	0.0	0.0
Sewage sludge incineration	kt dry	102.6	102.4	100.8	109.0
Open burning of natural residues in agriculture	kt	11.5	11.4	11.3	11.2
Open burning of natural residues in forestry	kt	11.5	11.4	11.3	11.2
Open burning of natural residues in private households	kt	1.2	1.2	1.2	1.2
Total	kt	147.9	146.7	144.8	151.9
Cremation	Numb.	52'813	52'530	50'567	53'550

7.4.3 Uncertainties and Time-Series Consistency

A preliminary uncertainty assessment based on expert judgment results in high uncertainties for CO_2 and CH_4 of 40% and 60% of emission estimates, respectively, and for N_2O in low uncertainty of 40% of emission estimates (see Table 1-11 for quantification of “low” and “high”).

Consistency: Time series for 5C Waste incineration and open burning of waste are all considered consistent.

7.4.4 Source-Specific QA/QC and Verification

The general QA/QC measures are described in section 1.2.3.

7.4.5 Source-Specific Recalculations

Due to the recalculation of the C-content of municipal solid waste and the changes in the shares of fossil C in waste (see recalculations in 1A1a Public Electricity and Heat Production), the EF for illegal waste burning is assumed to have changed accordingly.

In previous submissions the amount of sewage sludge burnt in SSIP has been interpolated between the year 2006 (last available data) and the projections for 2015. Starting from this submission the amount is calculated based in the total amount of sewage sludge (as used in 5D1) and the amount burnt in MSWIP and in the cement industry (for the years 2010 onwards). This leads to changed AD starting from 2007.

7.4.6 Source-Specific Planned Improvements

There are no source-specific planned improvements in this sector.

7.5 Source Category 5D – Wastewater Treatment and Discharge

7.5.1 Source Category Description

Approach 1 Key category 5D

CH_4 emissions from wastewater treatment and discharge (level).

Approach 2 Key category 5D

CH_4 emissions from wastewater treatment and discharge (level).

The source category 5D1 Domestic Wastewater comprises all emissions from liquid waste handling and sludge from housing and commercial sources (including grey water and night soil). In Switzerland, municipal wastewater treatment (WWT) plants treat wastewater from single cities or several cities/municipalities together. Wastewater in general is treated in three steps: 1. Mechanical treatment, 2. Biological treatment, and 3. Chemical treatment. The treated wastewater flows into a receiving system (lake, river or stream). Pre-treated effluents from industries are also handled for final treatment in municipal WWT plants (see below). Switzerland's wastewater management infrastructure – comprising 849 WWT plants and 40’000-50’000 km of public sewers – is now practically complete (FOEN 2012h). In 2012, the vast majority of WWT plants applied an anaerobic sludge treatment with sewage gas recovery, and used the sewage gas for heat production. About 285 WWT plants also applied combined heat and power (CHP) units.

The source category 5D2 Industrial Wastewater comprises all emissions from liquid waste handling and sludge from industrial processes such as food processing, textiles, car-washing places, electroplating plants, and pulp/paper production. These processes may result in effluents with a high load of organics. Depending on the contaminants, an on-site pre-treatment is necessary in order to reduce the load of pollutants in the wastewater, to meet the regulatory standards (which are in place to preclude disruptions of the municipal WWT plants), and to reduce discharge fees. The on-site pre-treatment is generally anaerobic, in order to use the sewage gas as source for heat and power production. Currently, 22 industrial WWT plants pre-treat wastewater before its discharge to the domestic sewage system, where the industrial wastewater is additionally treated together with domestic wastewater in municipal WWT plants. Due to this strong connection with domestic wastewater treatment industrial wastewater is not identified as separate wastewater stream for emission calculations, but joined to the domestic wastewater treatment (see below).

Table 7-15 Specification of source category 5D Wastewater Treatment and Discharge. "EMIS 2015/…" refers to the internal documentation of the emission database and contains further references regarding specific AD and/or EF.

5D	Source	Specification	Data Source
5D1	Domestic wastewater	Emissions from liquid waste handling and sludge from housing and commercial sources	AD: EMIS 2015/5D1_5D2 Kläranlagen GHG (Wastewater Handling - Emissions of N_2O and CH_4) and SFOE 2014 EF: EMIS 2015/5D1_5D2 Kläranlagen GHG (Wastewater Handling - Emissions of N_2O and CH_4)
5D2	Industrial wastewater	Emissions of precursors from handling of liquid wastes and sludge from industrial processes (The GHG gases CH_4 and N_2O emissions are implemented in 5D1)	AD: EMIS 2015/5D2 Pre-treatment of industrial wastewater(other gases), and SFOE 2014 EF: EMIS 2015/5D2 Pre-treatment of industrial wastewater (other gases)
5D3	Other	Not occurring in Switzerland	

Category 5D contains all direct emissions from wastewater handling, including direct emissions of sewage gas (leakage), torching, combined heat and power (CHP) units, furnaces (only heat production), combustion of heating oil in boilers and engines, and upgrading of sewage gas to natural gas quality (which can then be fed into the natural gas network and/or used as fuel). However, wastewater treatment also leads to emissions reported in other categories, as illustrated in Figure 7-5 below.

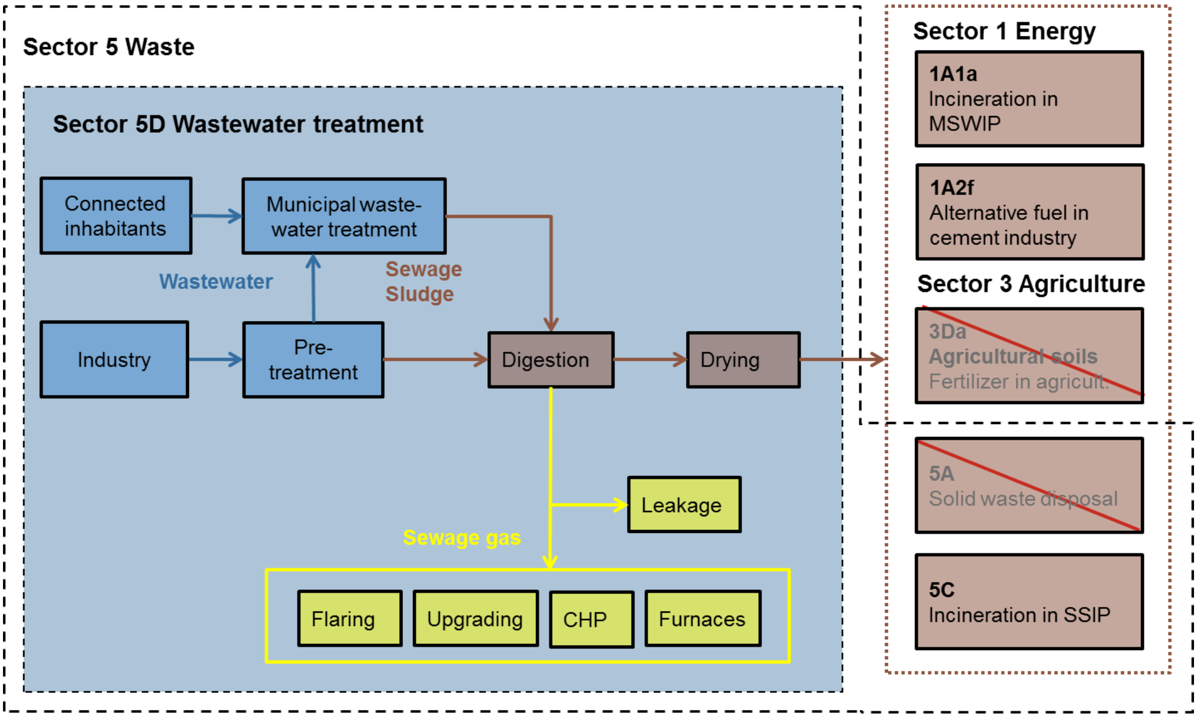


Figure 7-5 System boundaries of processes related to wastewater treatment. CHP= Combined Heat and Power Production. Sewage sludge is usually dried in sewage plants in Switzerland before being disposed of. Emissions associated with sewage sludge drying are assumed to be negligible. The discharge of sewage sludge on agricultural soils has been phased out since 2003 and is generally forbidden since 2008. Therefore, this process is crossed out in the figure. The same applies to solid waste disposal on land (5A). All sewage sludge is incinerated either in MSW incineration plants (1A1a), SS incineration plants (5C) or used as alternative fuel in the cement industry (1A2f).

7.5.2 Methodological Issues

For commercial and industrial wastewater treatment country-specific methods were used so far. In order to comply with the 2006 IPCC Guidelines (IPCC 2006), the methods for CH_4 and N_2O emissions have been modified.

a) CH_4 Emissions

Methodology

CH_4 emissions from wastewater treatment and discharge take into account emissions stemming from organically degradable material in wastewater and emissions related to sewage gas production (and recovery) from sewage sludge (in domestic as well as industrial installations). As noted above most industrial wastewater may be treated together with domestic wastewater in municipal WWT plants. The industrial/commercial contribution to total CH_4 emissions from wastewater is thus taken into account in the calculation of CH_4 emissions from domestic wastewater by means of a correction factor for additional industrial biochemical oxygen demand (BOD) discharged into the domestic sewer system. However, industries handling wastewater with high BOD usually use anaerobic digesters to produce sewage gas. The emissions related to sewage gas production (and recovery) during industrial pre-treatment of wastewater are also taken into account in the calculation of emissions from municipal WWT plants, because the underlying Swiss renewable energy statistics in Switzerland (see below) does not differentiate between sewage gas production in domestic and industrial WWT plants.

Accordingly, total CH_4 emissions from domestic and industrial wastewater treatment and discharge are calculated as the sum of two terms:

$$CH_{4,total} = CH_{4,wastewater} + CH_{4,sewage\ gas}$$

(i) Wastewater

In accordance with the 2006 IPCC Guidelines (IPCC 2006) the contribution of wastewater severed to WWT plants is determined by:

$$CH_{4,wastewater} = EF_{wastewater} * T_{Plant} * TOW$$

$EF_{wastewater}$ corresponds to the emission factor (see below), T_{Plant} to the fraction of population connected to municipal WWT plants in each year and TOW to the total organically degradable material in the wastewater per year.

From all inhabitants (urban and rural) 90% were connected to WWT plants in 1990, and this percentage reached 97% in 2006, remaining constant thereafter. Switzerland reports emissions only from wastewater discharged to the public sewer system, without taking into account potential emissions from wastewater of unconnected inhabitants. However, emissions from the small fraction of wastewater not treated in WWT plants (since 2006 the wastewater from 3% of the population) are negligible. Federal law only permits alternative treatment systems in remote and sparsely populated regions. Some of such alternative systems treat wastewater very similar to centralized WWT plants, often under aerobic conditions. The sewage sludge from these small scale treatment installations is either dealt with by centralized WWT plants or MWIP (municipal waste incineration plants). Simpler systems are e.g. septic tanks with at least three chambers. However, the production of CH_4 in an anaerobic environment is strongly temperature dependent and significant CH_4 production is unlikely below 15°C due to the inactivity of methanogens (see 1996 IPCC Guidelines, chp. 6.3.2, p. 6.14, and also chp. 6.1, p. 6.7). As in Switzerland alternative systems are typically buried, the wastewater reaches the rather constant temperature of the surrounding soil, approximately corresponding to the mean annual air temperature. At Grono, the warmest place in Switzerland, the mean annual temperature is 12.4°C. Accordingly, in alternative treatment systems the temperature of the wastewater is too low to produce substantial CH_4 emissions. CH_4 emissions from wastewater produced by inhabitants not connected to municipal WWT plants are thus considered insignificant and set to zero in the Swiss Greenhouse Gas Inventory.

ii) Sewage gas

The CH_4 emissions resulting from sewage gas treatment (aiming at stabilizing the sewage sludge and producing sewage gas) are calculated based on a country-specific implied emission factor ($EF_{sewage\ gas}$), which is normalized with population (P):

$$CH_{4,sewage\ gas} = EF_{sewage\ gas} * P$$

Emission factors

(i) Wastewater

The wastewater of all connected inhabitants, i.e. virtually all wastewater generated in Switzerland, is sewered to WWT plants using closed sewer systems. The emission factor according to the 2006 IPCC Guidelines (IPCC 2006), Equation 6.2, is represented by the product of the maximum CH_4 producing potential (B_o, default value 0.60 kgCH_4/kgBOD) and the methane correction factor (MCF) for the wastewater treatment and discharge system. For the wastewater sewered to centralized WWT plants, the 2006 IPCC Guidelines (IPCC 2006) propose that the MCF is zero (range 0.0-0.1) for well managed aerobic WWT plants. While WWT plants are generally well managed in Switzerland and mostly operated aerobically (with the exception of sewage sludge treatment, which is considered separately, see below), some CH_4 emissions may still occur. Therefore, the MCF is set to 0.05 (corresponding to the mid-value of the range of well managed aerobic WWT plants), which also brings total CH_4 emissions from WWT in Switzerland to similar values as estimated by Hiller et al. (2014) in their peer-reviewed study. This leads to the following emission factor, which is constant over the period 1990-2013:

$$EF_{wastewater} = B_0 * MCF = 0.60 \frac{kgCH_4}{kgBOD} * 0.05 = 0.03 \frac{kgCH_4}{kgBOD} \qquad \text{(IPCC 6.2)}$$

As mentioned above the maximum CH_4 producing capacity of the wastewater not treated in WWT plants is zero, as the wastewater has a temperature most likely too low to produce significant amounts of CH_4. Accordingly, the EF for wastewater not treated in WWT plants is zero and the corresponding emission is zero, too.

(ii) Sewage gas

To calculate the country-specific implied emission factor $EF_{sewage\ gas}$ for CH_4 emissions from sewage gas treatment the total sewage gas production (in domestic and industrial systems) is taken into account based on detailed Swiss renewable energy statistics in Switzerland (Schweizerische Statistik der erneuerbaren Energien, 2013). These statistics provide the amount of sewage gas used in furnaces and CHP installations, as well as the amount of sewage gas upgraded to natural gas quality. As in previous inventories, it is assumed that 2% of the total amount of sewage gas is flared and 0.75% of the total amount is leaking. It is further assumed that 5% of the upgraded gas leaks as well. As previously, a calorific value of 19‘945 kg CH_4/TJ is used. With these assumptions an implied emission factor ($EF_{sewage\ gas}$) of about 60 g/inhabitant/year results e.g. for 2013 (EMIS2015/5D1). The emission factor is adapted on a yearly basis due to respective changes in population and the amount of total sewage gas production.

(iii) Values of emission factors referred to the number of inhabitants

The values of CH_4 emission factors are summarized in Table 7-16

Table 7-16 Country-specific CH_4 emission factors 5D Wastewater treatment and discharge 2013 referred to the number of inhabitants. Detailed information is given in EMIS 2015/5D1_5D2 Kläranlagen GHG (Wastewater Handling - Emissions of Nitrous Oxide (N_2O) and Methane (CH_4), Update to the 2006 IPCC Guidelines).

5D Wastewater treatment and discharge	CH_4 [kg/inhabitant/year]
Organically degradable material	0.80
Sewage sludge removal and CH_4 recovery	0.06

Activity Data

(i) Wastewater

In correspondence with the emission factor $EF_{wastewater}$ given above, the activity data is the fraction of population connected to municipal WWT plants (T_{plant}), as well as the total organically degradable material (*TOW*) in domestic and industrial/commercial wastewater. According to the 2006 IPCC Guidelines (IPCC 2006), Equation 6.3, TOW is calculated by

$$TOW = P * BOD * 0.001 * I * 365 \qquad \text{(IPCC 6.3)}$$

TOW is given in kg BOD/yr (BOD: biochemical oxygen demand) and P is the population (see Table 7-17). For BOD the default value for Europe given by the 2006 IPCC Guidelines (IPCC 2006) is used for Switzerland (60 g/inhabitant/day). It corresponds to the correction factor for additional industrial/commercial BOD discharged into domestic sewers with default value 1.25. While the amount of sewage sludge removed from WWT plants is known, detailed information about its BOD content is not available. Therefore, the amount of BOD removed with sewage sludge is set to zero, in accordance with the default value given by the 2006 IPCC Guidelines (IPCC 2006).

Time series of the activity data are shown in Table 7-17.

(ii) Sewage gas

As elaborated above, a per capita CH_4 emission factor ($EF_{sewage\ gas}$) is calculated for CH_4 emissions from separate sewage sludge treatment, and the respective activity data is population (P, see Table 7-17).

b) N_2O Emissions

Methodology

N_2O emissions are calculated according to the method suggested by IPCC (2006) by calculating direct N_2O emissions from wastewater effluent, but also from centralized WWT plants.

(i) N_2O emissions from WWT plants

In accordance with the 2006 IPCC Guidelines (IPCC 2006), direct N_2O emissions from centralized WWT plants and N_2O emissions from wastewater effluent are calculated.

Direct N_2O emissions from WWT plants are determined with equation 6.9 of the 2006 IPCC Guidelines (IPCC 2006):

$$N_2O_{PLANTS} = EF_{PLANT} * P * T_{PLANT} * F_{IND-COM} \qquad \text{(IPCC 6.9)}$$

N_2O_{PLANTS} corresponds to the total N_2O emissions from WWT plants in kg N_2O/yr, P to the population, T_{PLANT} to the degree of utilization of modern, centralized WWT plants (%), $F_{IND-COM}$ to the correction factor for industrial and commercial co-discharged protein, and EF_{PLANT} to the emission factor from the plants.

(ii) N_2O emissions from wastewater effluents

The following equation is provided in the 2006 IPCC Guidelines (IPCC 2006) for the N_2O emissions from wastewater effluent (Equation 6.7):

$$N_2O_{Effluent} = EF_{EFFLUENT} * N_{EFFLUENT} * 44/28 \qquad \text{(IPCC 6.7)}$$

$N_2O_{Effluent}$ corresponds to the total N_2O emissions from effluents (kg N_2O/yr), $N_{EFFLUENT}$ to the total amount of nitrogen discharged to the aquatic environment (kg N/yr), and $EF_{EFFLUENT}$ to the emission factor for N_2O emissions from discharged wastewater (kg N-N_2O/kg N). The following equation allows for the calculation of the total amount of nitrogen in the wastewater ($N_{EFFLUENT}$, kg N/yr, Equation 6.8 in the 2006 IPCC Guidelines):

$$N_{EFFLUENT} = (P * Protein * F_{NPR} * F_{NON-CON} * F_{IND-COM}) - N_{SLUDGE} - N_{WWT} \qquad \text{(IPCC 6.8)}$$

P corresponds to the population, Protein to the annual per capita protein consumption (kg Protein/inhabitant/yr), and F_{NPR} to the fraction of nitrogen in protein. $F_{NON-CON}$ is a factor accounting for non-consumed protein added to the wastewater. $F_{IND-COM}$ is a factor accounting for industrial and commercial co-discharged protein into the sewer system. N_{SLUDGE} is the amount of nitrogen removed with sewage sludge (kg N/yr), calculated as the product of sludge amount per year and nitrogen concentration. The default value according to the 2006 IPCC Guidelines would be zero, but detailed data about sewage sludge removal as well as the nitrogen content of the sewage sludge is available for Switzerland (Külling et al. 2002a). In Switzerland sewage sludge is mostly burnt today in waste incineration plants and (cement) industry, previously it has also been used as fertilizer (now forbidden). N_{WWT} corresponds to the amount of nitrogen directly emitted by WWT plants in form of N_2O (N_2O_{Plants}, see calculation above).

Emission factors

(i) N_2O emissions from WWT plants

The IPCC default emission factor is applied: EF_{PLANT} = 3.2 g N_2O/inhabitant/yr (IPCC 2006).

(ii) N_2O emissions from wastewater effluents

The IPCC default emission factor is applied: $EF_{EFFLUENT}$ = 0.005 kg N_2O/kg N (IPCC 2006).

Activity Data

(i) N_2O emissions from WWT plants

The needed time-dependent and country-specific activity data are summarized in Table 7-17:

- Population (P)
- Degree of utilization of modern, centralized WWT plants (T_{PLANT})

In addition, the following constant factor is used:

- Industrial/commercial co-discharged protein, IPCC default value: $F_{IND\text{-}COM}$ = 1.25 (IPCC 2006)

(ii) N_2O emissions from wastewater effluents

The time-dependent and country-specific activity data are also summarized in Table 7-17:

- Population (P)
- Annual per capita protein consumption (Protein)
- Mass of nitrogen contained in the removed sludge (N_{SLUDGE})

In addition, the following constant factors are used:

- Fraction of nitrogen in protein, IPCC default value: F_{NPR} = 0.16 kg N/kg Protein (IPCC 2006).
- Factor accounting for non-consumed protein added to the wastewater, IPCC default value: $F_{NON\text{-}CON}$ = 1.1 (IPCC 2006). Note that this value is recommended for countries without garbage disposal (which holds for Switzerland as it is illegal to discharge solid and liquid garbage with the wastewater, see Article 10 in the Waters Protection Ordinance, Swiss Federal Council 2014).
- Industrial/commercial co-discharged protein, IPCC default value: $F_{IND\text{-}COM}$ = 1.25 (IPCC 2006).

Table 7-17 Activity data 5D Wastewater Treatment.

5D Wastewater treatment and discharge	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Population	inhabitants in 1000	6'796	6'880	6'943	6'989	7'037	7'081	7'105	7'113	7'132	7'167
Fraction of population connected to wastewater treatment plants (T_{plant})	%	90.0	91.0	91.5	92.0	93.0	93.5	94.0	94.5	95.0	95.3
Connected inhabitants	inhabitants in 1000	6'116	6'261	6'353	6'430	6'544	6'621	6'679	6'722	6'775	6'830
Protein consumption	kg/person/a	37.9	38.1	38.0	37.2	37.2	36.8	36.6	36.7	36.7	36.3
N sludge	N in t/a	9'465	9'345	9'226	9'107	8'989	9'009	9'030	9'051	9'071	9'092
N WWT	N in t/a	15.6	15.9	16.2	16.4	16.7	16.9	17.0	17.1	17.2	17.4
CH_4 losses	kg/person/a	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

5D Wastewater treatment and discharge	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Population	inhabitants in 1000	7'209	7'285	7'343	7'405	7'454	7'501	7'558	7'619	7'711	7'801
Fraction of population connected to wastewater treatment plants (T_{plant})	%	95.4	95.7	96.0	96.3	96.6	96.8	97.0	97.0	97.0	97.0
Connected inhabitants	inhabitants in 1000	6'877	6'972	7'049	7'131	7'201	7'261	7'331	7'390	7'480	7'567
Protein consumption	kg/person/a	36.9	36.0	35.7	36.3	36.5	36.1	36.8	37.1	37.0	37.4
N sludge	N in t/a	8'831	8'765	8'700	8'809	8'918	9'026	9'135	9'135	9'135	9'135
N WWT	N in t/a	17.5	17.7	17.9	18.2	18.3	18.5	18.7	18.8	19.0	19.3
CH_4 losses	kg/person/a	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.04

5D Wastewater treatment and discharge	Unit	2010	2011	2012	2013
Population	inhabitants in 1000	7'878	7'912	7'997	8'089
Fraction of population connected to wastewater treatment plants (T_{plant})	%	97.0	97.0	97.0	97.0
Connected inhabitants	inhabitants in 1000	7'642	7'675	7'757	7'846
Protein consumption	kg/person/a	38.0	38.5	38.5	38.5
N sludge	N in t/a	9'135	9'135	9'135	9'135
N WWT	N in t/a	19.5	19.5	19.7	20.0
CH_4 losses	kg/person/a	0.05	0.05	0.05	0.06

c) Other gases

The sewage gas production generates emissions of further gases from flaring: CO_2 (biogenic), NO_x, CO, NMVOC, SO_2. The emissions are calculated by multiplying population with country-specific emission factors based on measurements and expert estimates, documented in the EMIS 2015/5D1 Wastewater Treatment Plants and EMIS 2015/5D2 Pre-treatment of industrial wastewater. The emission factors used are summarized in the following Table 7-18:

Table 7-18 Emission Factors of other gases /air pollutants for 5D Wastewater treatment in 2013.

5D Wastewater treatment and discharge	CO_2 biog.	NO_x	CO	NMVOC	SO_2
	kg/inhabitant	g/inhabitant			
5D1 Domestic wastewater	14.7	24	42	0.5	3
5D2 Industrial wastewater	1.9	2.5	4.0	0.07	0.26

7.5.3 Uncertainties and Time-Series Consistency

Uncertainty in CH_4 and N_2O emissions from 5D

a) CH_4 Emissions

The default values of the 2006 IPCC Guidelines (IPCC 2006) are adopted to estimate the uncertainty of the CH_4 emissions. The following specifications are given:

- Activity data: Uncertainties of the single factors U(population) = 5%, U(BOD) = 30%, U(I) = 20% lead to an aggregated uncertainty of U(AD) = 36%.
- CH_4 emission factor: Uncertainties of the single factors U(B_0) = 30%, U(MCF) = 10% (well managed plants) lead to an aggregated uncertainty of U(AD) = 32%.
- Combined uncertainty U(Em CH_4) = 48%.

b) N_2O Emissions

By applying the default uncertainties of the 2006 IPCC Guidelines (chp. 6, table 6.11) for the activity data (population, protein consumption etc.) a total uncertainty of 32% results.

For the emission factor the 2006 IPCC Guidelines provide default values, too. However, the range for $EF_{EFFLUENT}$ covers an interval of 0.0005 – 0.25 (with default value 0.005). If this range is interpreted as the 95% uncertainty interval, a symmetrised uncertainty of 2500% would result, which is not considered appropriate. The 2006 IPCC Guidelines (IPCC 2006) do not explain how to apply the range, wherefore the default uncertainty is not adopted. Instead, the uncertainty is based on expert judgments who assume a high uncertainty of the N_2O emissions in Switzerland. By means of Table 1-11 this qualitative estimation corresponds to 150% for the combined uncertainty. This value is used for the uncertainty analyses of NIR chapter 1.7.

Consistency: Time series for 5D Wastewater treatment and discharge are all considered consistent.

7.5.4 Source-Specific QA/QC and Verification

The general QA/QC measures are described in section 1.2.3.

7.5.5 Source-Specific Recalculations

The methods to calculate emissions from wastewater have been updated according to the 2006 IPCC Guidelines (IPCC 2006). The time series of CH_4 and N_2O emissions have fully been recalculated.

7.5.6 Source-Specific Planned Improvements

There are no source-specific planned improvements for this category.

7.6 Source Category 5E – Other

7.6.1 Source Category Description

Source category 5E Other is **not a key category**.

The source category 5E Other comprises NMVOC and CO emissions from car shredding stemming from residues of fuels (gasoline, diesel) and motor oil in the tanks and motors of the shredded vehicles. GHG emissions do not occur.

Table 7-19 Specification of source category 5E Other / Car Shredding "EMIS 2015/…" refers to the internal documentation of the emission database and contains further references regarding specific AD and/or EF.

5E	Source	Specification	Data Source
5E	Car shredding plants	Emissions from car shredding plants	AD, EF: EMIS 2015/5E Shredder Anlagen

7.6.2 Methodological Issues

Methodology

For the emissions from car shredding a country-specific method is used. NMVOC and CO emissions are calculated by multiplying the quantity of scrap by the emission factors.

Emission Factors

An emission factor of 100 g NMVOC per ton of shredded vehicle is applied for the period 1990-1995. From 2000 onward, 200 g/t are used. Between 1995 and 2000 the values are linearly interpolated (EMIS 2015/5E Shredder Anlagen). For CO a constant emission factor is applied over the whole period.

Table 7-20 CO, NMVOC emission factors 5E Other / Car Shredding in 2013.

5E Other waste	Unit	CO	NMVOC
Shredding	g/t scrap	5	200

Activity Data

Activity data for shredding stem from the internal waste statistics of FOEN (see also EMIS 2015/5E Shredder and

Table 7-21 Activity data 5E Other / Car Shredding.

5E Other waste	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Shredding	kt	280	284	288	292	296	300	300	300	300	300

5E Other waste	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Shredding	kt	300	300	300	300	300	300	300	300	300	300

5E Other waste	Unit	2010	2011	2012	2013
Shredding	kt	300	300	300	300

7.6.3 Uncertainties and Time-Series Consistency

An uncertainty of 20% for the emission factor and 10% for the activity data are assumed.

Consistency: Time series for 5E Other are all considered consistent.

7.6.4 Source-Specific QA/QC and Verification

The general QA/QC measures are described in section 1.2.3.

7.6.5 Source-Specific Recalculations

There are no source-specific recalculations in this category.

7.6.6 Source-Specific Planned Improvements

There are no source-specific planned improvements in this category.

8 Other

8.1 Overview

8.1.1 Greenhouse Gas Emissions

Within the sector 6 Other emissions from various sources are considered:

- Fire damage estates
- Fire damage motor vehicles

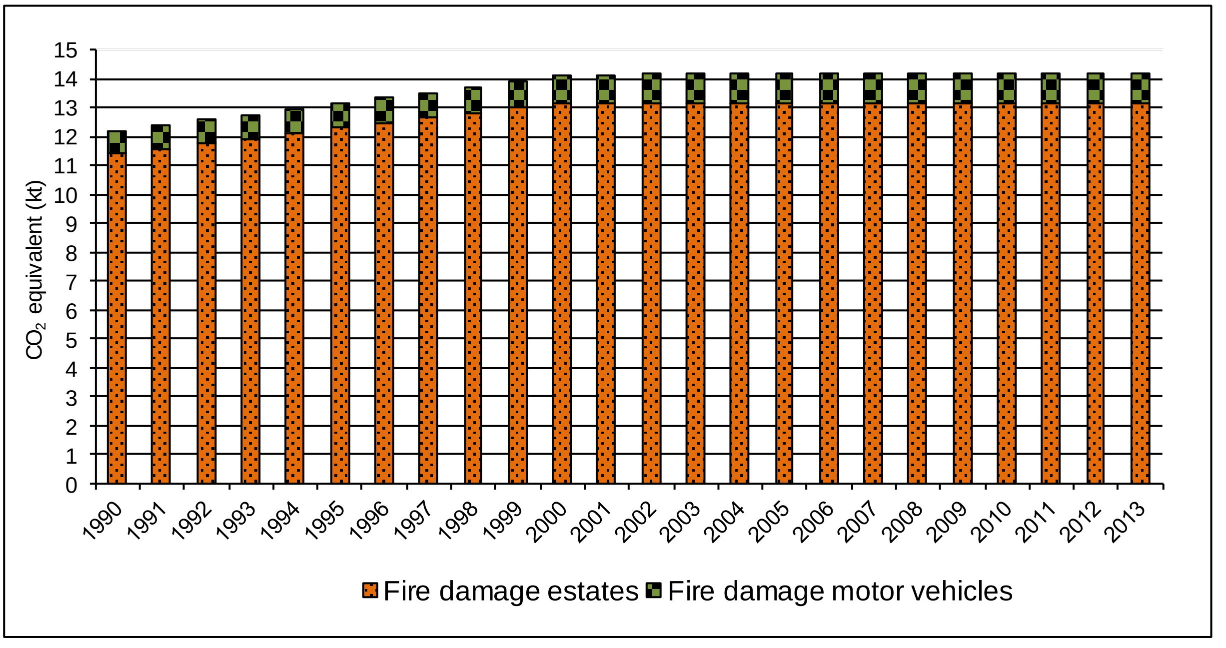


Figure 8-1 Switzerland's greenhouse gas emissions in the sector 6 Other 1990–2013.

Table 8-1 Trend of total GHG emissions from the sector 6 Other in Switzerland 1990-2013.

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	CO_2 equivalent (kt)									
CO_2	11.0	11.2	11.3	11.5	11.7	11.9	12.1	12.3	12.5	12.7
CH_4	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
N_2O	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sum	12.2	12.4	12.6	12.8	13.0	13.2	13.4	13.5	13.7	13.9

Gas	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	CO_2 equivalent (kt)									
CO_2	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9
CH_4	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
N_2O	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sum	14.1	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2

Gas	2010	2011	2012	2013
	CO_2 equivalent (kt)			
CO_2	12.9	12.9	12.9	12.9
CH_4	0.7	0.7	0.7	0.7
N_2O	0.6	0.6	0.6	0.6
Sum	14.2	14.2	14.2	14.2

In the sector 6 Other a total of 14.2 kt CO_2 equivalents was emitted in the year 2013. 93% of the emissions stem from “fire damage estates”, the rest from “fire damage motor vehicles”. The total greenhouse gas emissions of this sector show an increase of 16% from 1990 until 2013.

8.2 Source Category – Other non-specified

8.2.1 Source Category Description

Approach 1 and 2 key category 6

Source category 6 Other is not a key category.

The sources reported in source category 6 Other are depicted in Table 8-2.

Table 8-2 Specification of source category 6 Other. EMIS 2015/… refers to the internal documentation of the emission database and contains further references regarding specific AD and/or EF.

6	Source	Specification	Data Source
6Ad	Fire damage estates	Emissions from fires in buildings.	EMIS 2015/6Ad “Brand- und Feuerschäden Immobilien”
6Ad	Fire damage motor vehicles	Emissions from fires in motor vehicles.	EMIS 2015/6Ad “Brand- und Feuerschäden Motorfahrzeuge”

8.2.2 Methodological Issues

Methodology

a) Fire damage estate

For the emissions from fire damages estate a country-specific method is used. Emissions are calculated by multiplying the quantity of scrap by the emission factors.

b) Fire damage motor vehicles

For the emissions from fire damages motor vehicles a country-specific method is used. Emissions are calculated by multiplying the quantity of scrap by the emission factors.

Emission Factors

a) Fire damages in estates

Emission factors for CO_2, CO, NO_x and SO_2 are country-specific based on measurements and expert estimates originally completed for illegal waste incineration. It is assumed that emissions are similar to emissions of fire damage in estates (EMIS 2015/6Ad “Brand- und Feuerschäden Immobilien”).

The fraction between fossil and biogenic CO_2 emissions is assumed to remain constant since 2000 with 80% being fossil and 20% biogenic CO_2 emissions. Before 2000, it is assumed that the fraction of fossil CO_2 emissions from burnt goods has been increasing linearly from 20% in 1950 to 80% in 2000.

b) Fire damages in motor vehicles

Emission factors for CO_2, CO, NOx and SO_2 are country-specific based on measurements and expert estimates originally gained from the combustion of cables, documented in EMIS 2015/6Ad “Brand- und Feuerschäden Motorfahrzeuge”.

Emissions for CH_4 from fire damage in motor vehicles are reported as well, while N_2O emissions have not been estimated for this source.

Table 8-3 Emission Factors for fire damages in 2013 (EMIS 2015/6Ad).

6Ad Fire damages	CO_2 biogenic	CO_2 fossil	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
	t / t burned good							
Fire damage estates	0.40	1.5	0.003	0.00025	0.0020	0.100	0.016	0.001
Fire damage motor vehicles	NO	1.5	0.005	NE	0.0013	0.002	0.002	0.005

Activity Data

a) Fire damage in estates

Based on average damage sums from insurances between 1992 and 2001, the average damage sum per fire case is estimated at 15’600 CHF representing 780 kg of flammable material per fire case. Further assuming that not the whole amount burns down due to the intervention of the fire brigade, an amount of 400 kg of burnt material per fire case is estimated. On average between 1992 and 2001, 20’650 cases of fire incidents happened each year. For emission calculation, a constant number of 20’000 fire cases per year is assumed (EMIS 2015/6Ad “Brand- und Feuerschäden Immobilien”).

Activity data is the weight of burnt goods, calculated according to the following rule of proportion: 400 kg of burnt goods per incidence of fire cases in estates (EMIS 2015/6Ad “Brand- und Feuerschäden Immobilien”). Activity data for estates is not estimated on a year to year basis but is assumed to be at a constant 8 kt for the whole time period since 1990.

b) Fire damages in motor vehicles

Based on data from a Swiss insurance company with 25% market share in 2002, the number of reported vehicle fires was extrapolated. Based on this estimate and the total vehicle number of Switzerland it was estimated that one fire case per 790 vehicles occurs per year and this probability was assumed to remain constant from 1990-2013. Multiplied with the actual vehicle number, the number of burnt vehicles in Switzerland per year is obtained (EMIS 2015/6Ad “Brand- und Feuerschäden Motorfahrzeuge”).

Activity data is the weight of burnt goods, calculated according to the following rule of proportion: 100 kg of burnt goods per incidence of burnt vehicles (EMIS 2015/6D “Brand- und Feuerschäden Motorfahrzeuge”).

Table 8-4 Activity data: Burnt goods from 1990 to 2013 (source EMIS 2015/6D).

6Ad Fire damages	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Fire damage estates	Gg	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Fire damage motor vehicles	Gg	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6

6Ad Fire damages	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Fire damage estates	Gg	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Fire damage motor vehicles	Gg	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6

6Ad Fire damages	Unit	2010	2011	2012	2013
Fire damage estates	Gg	8.0	8.0	8.0	8.0
Fire damage motor vehicles	Gg	0.6	0.6	0.6	0.6

8.2.3 Uncertainties and Time Series consistency

Uncertainty of CO_2, CH_4 and N_2O emissions is estimated to be high (according to Table 1-11).

Consistency: Time series for 6Ad Fire damages are all considered consistent.

8.2.4 Source-Specific QA/QC and Verification

The general QA/QC measures are described in section 1.2.3.

8.2.5 Source-Specific Recalculations

No recalculations for this submission.

8.2.6 Source-Specific Planned Improvements

There are no source-specific planned improvements in this category.

9 Indirect CO_2 and Nitrous Oxide Emissions

9.1 Overview

In this chapter indirect CO_2 emissions are reported that result from the decomposition of NMVOC in the atmosphere. Please note that emissions reported in this chapter are not accounting to the national total and reporting is voluntary.

9.2 Source Category – Indirect CO_2 and Nitrous Oxide Emissions

9.2.1 Source Category Description

Approach 1 and 2 key category 9

Source category 9 Indirect CO_2 and Nitrous Oxcide Emissions is not a key category.

9.2.2 Methodological Issues

The NMVOC emissions are calculated as the difference of VOC and CH_4 emissions. Based on this the indirect CO_2 emissions due to decomposition of NMVOC in the atmosphere are calculated using a carbon content fraction of 0.6 according to the 2006 IPCC Guidelines (IPCC 2006).

Emission Factors

The emission factor for indirect CO_2 emissions from decomposition of NMVOC in the atmosphere is country-specific and determined as 2.2 kt CO_2/kt NMVOC (carbon content fraction * molecular weight of carbon dioxide / molecular weight of carbon).

For indirect emissions from Oil (1B2a) concerning NMVOC a conversion factor of 0.86 g C/g NMVOC = 3.15333 g CO_2/g NMVOC is used. This value was adopted from the NIR of the Netherlands, because it is assumed that the NMVOC emitted from refineries are mainly hydrocarbons with a high C-content. In the NIR of the Netherlands (2005), C-contents for NMVOCs are given that have been used for comparison. Calculated with the NMVOC emissions in 1990 this leads to an emission factor of 1'356 g CO_2 /t crude oil used. This emission factor is kept constant for the whole time series.

Activity Data

Activity data is the sum of total NMVOC related activity as reported in chapter 4 for each individual source category from IPPU.

9.2.3 Uncertainties and Time Series consistency

Uncertainties are not estimated since the emissions from this category are not included in the uncertainty analyses.

Consistency: Time series Indirect CO_2 and nitrous oxide emissions are all considered consistent.

9.2.4 Source-Specific QA/QC and Verification

The very same QA/QC and Verification procedures are conducted as for NMVOC related source categories in chapter 4 IPPU.

9.2.5 Source-Specific Recalculations

See NMVOC related recalculations reported in chapters 4 and 10.1.

9.2.6 Source-Specific Planned Improvements

No planned improvements envisaged.

10 Recalculations and improvements

10.1 Explanations and Justifications for Recalculations, including in Response to the Review Process

The Inventory Development Plan is regularly updated, based on the “Reports of the individual review of the greenhouse gas inventory of Switzerland” (e.g. UNFCCC 2014), the outcome of domestic reviews, and other suggestions and feedback from the QA/QC procedures implemented in the inventory preparation process. The IDP represents the main instrument for continuous improvement of the Swiss GHG inventory in subsequent inventory cycles. It includes suggestions and recommendations for recalculations that have an impact on emission levels in the corresponding sectors.

The processing of the expert review team’s recommendations in the course of inventory preparation and compilation led to several recalculations and improvements (Table 10-1). Further recalculations had to be carried out due to improvements in some sectors. The details are explained below. An extensive list with all detailed recalculations and specifics of the recalculations is compiled by the EMIS experts and available to the reviewers on demand (in German/French only).

Table 10-1 Recommendations from the ERT (FCCC/ARR/2014/CHE) and explanations for implementation 2015.

NFR Code	Summary of recommendation in ARR (table 9)	Implementation date	Details
cross-cutting	12. Report the same and correct information in the CRF tables and the NIR and improve the QC procedures at the final stage of the inventory compilation process	Submission 2015	QC procedures have been re-assessed. Given the current situation with the CRF-reporter (as of February 2015), preparation of the 2015 submission had to be improvised and procedures adjusted. Hopefully, the situation will normalize for future submissions.
cross-cutting	13. Improve the transparency of the reporting by filling in all requested information in the CRF tables	Submission 2015	CRF tables will be completed according to the revised reporting guidelines.
cross-cutting	15. Make the description of the QA/QC system more transparent by updating the section of the NIR on “Responsibilities and coordination of QA/QC activities” with relevant information. Confirm that national statistics agencies have implemented adequate QC procedures and report on the progress made.	Submission 2015	The description of the national system and the inventory QA/QC system has been completely revised (see NIR chapter 1.2-1.4). The national statistics agencies comply with the requirements and quality standards set out in the federal legislation and in the "Charta öffentliche Statistik".
1A	23. Use the results of a study aimed at reassessing the CO2 EFs and net calorific values (NCVs) for liquid fuels	Submission 2015	The results of the study reassessing the CO2 EFs and NCVs for liquid fuels are now incorporated in the reporting of respective emissions. Explanations and references to the sources of the new values are described in NIR chapter 3.2.4.2.
1A	27. Disaggregate the reporting of fuels used for non-energy purposes	Submission 2015	In the submission 2015 for the first time fuels used for non-energy purposes are reported on disaggregated level. However, since this information is confidential it is only reported in the confidential version of the NIR document in chapter 3.2.3.
1A	28. Implement the plan to estimate country-specific CO2 EFs	Submission 2015	Country-specific CO2 EFs have now been revised based on a recent calculations by FOEN that are based on data from the Swiss Gas and Water Association and Quantis (2014) and are described in NIR chapter 3.2.4.2. The revised EF have been now used for the estimation of CO2-Emissions.
1A1a	36. Include the table with N2O EFs for municipal waste incineration plants, with brief and relevant explanatory information in the NIR	Submission 2015	N2O emission factors of 1A1a Municipal Solid and Special Waste Incineration are now described in the NIR chapter 3.2.5 and listed in table 3-24.
2A4	39. Specify that the clay contains limestone and dolomite in its NIR, thus explaining the allocation of emissions under this category	Submission 2015	The specification of limestone and dolomite containing clay and the emission reporting is provided in the NIR, chapter 4.2.2.4.

Table 10-1 continued.

NFR Code	Summary of recommendation in ARR (table 9)	Implementation date	Details
2B2	40. Include information supporting the use of a constant EF for the entire time series	Submission 2015	A denitrification system and an automatic control system for the ammonia addition was installed in 1988 and 1990, respectively, and no modification has been made in the production line. A constant N2O emission factor for 1990-2012 is assumed. A new catalyst installed in 2013 reduced the N2O-emissions which are measured online from 2013 onwards. The NOx emission factor for 1990-2012 is the mean value based on three plant specific measurements. The increased volume of the DeNOx plant and the new catalyst reduced the EF in 2013. Further details on NOx and N2O measurements and EF are included in NIR chapter 4.3.2.2.
3B	46. Report the deep litter AWMS for fattening calves, sheep and goats separately from the solid storage AWMS	Submission 2015	Information on the use of different AWMS is included in NIR chapter 5.3.2. The deep litter system is now reported separately from the solid storage AWMS. However, due to the structure of the CRF-Tables 3.B(a) and 3.B(b), the deep litter AWMS had to be reported in the same column as the poultry manure AWMS.
3D	47. Provide a comparison table which shows the results of the N2O emission calculation based on the IPCC method and the IULIA model	Submission 2015	A comparison table is included in NIR chapter 5.5.4 (Table 5-22).
4	51. Improve the description of the process that led to the definition of the combination categories in its 2015 annual submission, thereby increasing the transparency with respect to AD in the LULUCF sector	Submission 2015	Additional information on that process is included in NIR chapter 6.2.1. The chapters 6.2 and 6.3 are restructured according to the prescribed NIR-outline.
4	52. Provide more accurate ratios of both coniferous and deciduous species in mixed forests and of specific regions, reflecting the release of new data from the national forest inventory	Submission 2015	Most recent data from NFI4b are included (Table 6-11). Since uncertainties in some strata is still high because of low coverage, certain strata have been merged (see Chapter 6.4.2.3 and Table 6-13).
4	54.Incorporate in the NIR more detailed information from the supporting documents and the relevant references behind the reasoning of the decision to adopt a country-specific value for the carbon stock changes in organic soils and forest	Submission 2016	Background information or updated estimates will be available from an ongoing study at Agroscope and will be incorporated in the next submission (see Chapter 6.4.6).
4	55. Incorporate in the NIR all necessary information and references in combination with the expert judgement used to support the values reported in the Party's GHG inventory and reflect the realistic dimension for activities reported as afforestation in its national forest inventory	Submission 2016	A comparison with estimates from Austria is given in Chapter 6.4.4. The results of a Swiss study analyzing gross growth on afforestations will be implemented in the next submission (see Chapter 6.4.6).
4	57. Document all relevant and supporting information on the use of fertilizers in forests to cover the whole time series	Submission 2015	Additional information on the use of fertilizer is included in NIR chapter 6.4.2.12.
5	60. Provide additional detailed information related to the original data sources and estimation methods used to derive the EFs, which are documented in the EMIS comments	Submission 2015	Extended information is given in chp. 7.3.2, 7.4.2 and 7.5.2 in the corresponding sub-section "Emission factors"
5	61. Provide, in the cell comments of the CRF tables, the information on where the emissions and AD have been included for each use of the notation key "IE" for the whole time series	Submission 2015	*At the moment (2nd March 2015) the CRF tables are not available yet due to problems with the CRF-Reporter.*
5B	65. Improve the documentation in the NIR, standardize the terminology used and provide detailed information on the EFs and descriptions for all sources	Submission 2015	The term "fermentation" has been avoided and consequqntly been replaced by "digestion" throughot chp. 7.3. Additional information given in chp. 7.3.2, sub-sectipon "Emission factors".
5D	67.Include in the NIR information related to the emissions from wastewater of the inhabitants not connected to public wastewater treatment plants	Submission 2015	Emissions from wastewater treatment have been fully recalculated in line with IPCC 2006 Gudelines incl. Wastewater from inhab. not connected to a public wastewater treatment plant.
5C	68. Provide in the NIR detailed information on the EFs used	Submission 2015	Extended information is given in chp. 7.4.2, sub-section "Emission factors"

Table 10-2 Encouragements from the ERT (FCCC/ARR/2014/CHE) and explanations for implementation 2015.

NFR Code	Summary of encouragement in ARR (excerpt of paragraphs of ARR)	Imple-mented	Details
2C	41. In 2014, the CO2 EF used by the Party for iron and steel production was completely revised using new data from the two Swiss steel plants, avoiding double counting of emissions, since the previous CO2 EFs were based on measurements at the flue gas chimneys which included emissions from natural gas burned for energy purposes (NIR, page 206). ...In Switzerland, only secondary steel production occurs, which is steel production from recycled steel scrap, with relatively low emissions. The ERT acknowledges this clarification and encourages Switzerland to provide information on the carbon content of input materials to explicitly explain the link between exclusive secondary steel production and the low CO2 EFs used.	Sub 2015	Information on the carbon content of input materials, e.g. electrodes is provided in the confidential version of the NIR, chapter 4.4.2.1.
3A	44. Switzerland has used a tier 2 methodology to estimate CH4 emissions for all animal categories, with a country-specific EF developed in line with the IPCC good practice guidance. ... The ERT commends Switzerland for its efforts to improve its inventory and encourages the Party to improve transparency by including in the NIR a summary of the supporting information regarding the country-specific EF.	Sub 2015	CH4 emissions from livestock is described in NIR chapter 5.2 and 5.3. Due to the change to the new 2006 IPCC Guidelines and several additional methodological changes the chapters were completely revised and should include all supporting information. Additional information can also be found in ART 2013a.
3A	45. Switzerland has used the IPCC default values for the methane conversion rate (Ym) of 6.0 per cent for both mature dairy cattle and mature non-dairy cattle, and 5.7 per cent for young cattle in its CH4 emission estimates for cattle. ... The Party also provided information on its plan to review feed digestibility as well as nitrogen excretion and incorporate their results into a model that simultaneously estimates CH4 emissions from enteric fermentation, manure management and nitrogen excretion. The methane conversion factor (MCF) values will also be reviewed as part of the programme. The model will be available in early 2015 and will be further calibrated using appropriate country-specific parameters. The ERT commends Switzerland for these efforts and encourages the Party to reflect the result of the investigation on the Ym values in its CH4 emission estimates in the annual submission.	Sub 2015	New Ym values are described in NIR chapter 5.2.2.2. New MCF values are described in NIR chapter 5.3.2.2.
4	53. The meteorological data that drive the soil carbon model Yasso07, used by Switzerland to estimate temporal changes in carbon stocks in soil organic carbon, organic soil horizons and dead wood for productive forests, consist of annual values for temperature, precipitation and temperature amplitude....Switzerland also informed the ERT that uncertainty estimates are expected to become available in the future in the form of ensemble data sets, which can then be used in a Monte Carlo approach to assess the uncertainty of simulated decomposition of litter and dead wood using the Yasso07 model. The ERT encourages the Party to obtain such data to assess the uncertainty associated with the climate data. Also, the ERT encourages Switzerland to provide transparent information on the future application and parameterization of the model.	Sub 2015	The description of how meteorological data is included in Yasso07 is described in chapter 6.4.2.8. The section on uncertainty estimates from Yasso is extended in chapter 6.4.3. The implementation of new parameters and further improvements are described in Chapter 6.4.6 and in Didion et al. (2014).
4	56. For land-use changes involving buildings and construction, Switzerland has reported in its NIR (page 356) that only 50 per cent of the difference between the carbon stocks before and after the change is reported as a source or sink, respectively. ...Switzerland has chosen this criterion to reflect a domestic soil protection measure which has been adopted since 1998. In response to a question raised by the ERT during the review regarding the applicability of such a criterion for the years prior to 1998, Switzerland indicated that it regarded this approach as very close to the real conditions in the period prior to 1998, as supported by the presence of pre-existing legal instruments in force since 1986 and the traditionally very high awareness regarding soil fertility in Switzerland. The ERT encourages Switzerland to incorporate these explanations into its NIR.	Sub 2015	Additional explanations are given in chapter 6.8.2.2.
5A	64. Switzerland has estimated the amount of CH4 recovered from landfill gas as the sum of the amount of CH4 flared and the amount of CH4 used in cogeneration units. ... Also, noting that the reported amounts of CH4 flared are not based on the metered data, the ERT is of the view that the reported amounts of CH4 flared are undocumented estimates of landfill gas recovery and, therefore, the subtraction of the undocumented amount of CH4 flared is not in line with the IPCC good practice guidance. The ERT included this issue in its list of potential problems and further questions raised by the ERT and recommended that Switzerland either report the amount of CH4 recovered by flaring together with references documenting the amount of recovered CH4 that is flared, or estimate the CH4 emissions from solid waste disposal on land considering the amount of CH4 flared to be zero (the default value provided in the IPCC good practice guidance), for the entire time series. In response to the list of potential problems and further questions raised by the ERT during the review, Switzerland submitted revised estimates assuming the amount of CH4 flared to be zero. The impact of these revised emission estimates was an increase in CH4 emissions from solid waste disposal on land by 12.5 per cent (122.96 Gg CO2 eq) for the entire first commitment period (2008–2012). The ERT considers that the revised emission estimates resolved the issue. The ERT encourages Switzerland to conduct a further investigation to obtain relevant data to derive estimates of the amount of CH4 flared.	pending	A study is currently underway looking into ways to better quantify the amounts flared. Results are expected in the course of 2015.

General

For this submission the entire GHG inventory of Switzerland was revised and restructured according to the IPCC Guidelines (2006). In particular the global warming potential of CH_4, N_2O and synthetic gases (including new substances) were adjustes to new values. These changes explain the bulk of the differences resulting from the comparision of last with this submission (Table 10-3, Table 10-4).

1 Energy

- 1A: The entire emission factor model for 1A1a, 1A2f, 1A2gviii, 1A4ai, 1A4bi and 1A4ci Wood combustion has been revised for 1990-2012 resulting in corrected values for CH_4, CO and NMVOC.
- 1A: For wood combustion, the previously used country-specific value of the N_2O EF (1.6 g/GJ) has been replaced by the default value of the 2006 IPCC Guidlines (4.0 g/GJ) for the entire time series, based on a recommendation from the ERT (UNFCCC 2014c).
- 1A: In 1A1a, 1A2f, 1A2gviii, 1A4ai, 1A4bi and 1A4ci Wood combustion the AD (wood) of automatic boilers (> 50 kW) have been been revised for 1990-2012 due to recalculations in the Swiss wood energy statistics.
- 1A: Revised activity data for 1A1-1A5 for all years from 1990-2013 and all fuels due to a large-scale revision of the Swiss overall energy statistics.
- 1A: The default CO_2 emission factor for natural gas was replaced by a country-specific emission factor for the entire time period from 1990-2013.
- 1A: In earlier submissions, petroleum coke was reported toegether with coal, therefore, the N_2O emission factor for petroleum coke used was equal to the default emission factor for coal (1.6 g/GJ). As petreoleum coke is reported separately, default emission factor for petroleum coke from the IPCC Guidelines 2006 is used (0.6 g/GJ).
- 1A1a: Municipal waste incineration: Carbon content of waste is now based on annual data of net calorific value. Previously, the carbon content was based on expert judgements. The revised carbon content is lower than before, consequently also the CO_2-EF is lower. In addition, the share of fossil carbon in waste has been reassessed in order to derive a consistent time series.
- 1A1a: Municipal waste incineration: an error in the calculation of the weighted averages (waste amounts) of the EF for N_2O has been corrected. This leads to different EF for all years except 1990.
- 1A1a: Values of the amounts of biogas used and fed into the gas system have changed for the years 2011 and 2012 in the Swiss renewable energy statistics. This leads to changes in activity data of industrial biogas facilities.
- 1A1a: The amount of digestate used by agricultural biogas facilities has been corrected due to a plausibility check based on detailed data provided by Ökostrom Switzerland and FOEN monitoring reports for CO_2 compensation projects. This leads to lower amounts of digestate.
- 1A1a: In source category 1A1aiv Municipal waste incineration plants the CO_2 emissions from carbonate use for sulphur oxide removal are newly reported in the inventory for the years 1990-2006. There was only one plant using limestone for sulphur oxide removal.
- 1A2c: In 1A2c Steam production cracker byproducts the fuels liquefied petroleum gas and gas oil have been changed to so-called heating gas and gasolio, respectively, for the entire time series according to information from the plant. For the years 1990-2012 the CO_2 emission factors have been revised to plant-specific values whereas for CH_4

and N_2O emission factors default values according to 2006 IPCC Guidelines have been assumed.

- 1A2d: In source category 1A2d Cellulose production the CO_2 emissions from carbonate use for sulphur oxide removal are newly reported in the inventory fo the years 1990-2008.
- 1A2f: AD and EF for Cement production (furnaces) are now related to tons of clinker, and not to tons of cement anymore. Therefore all data have been converted to this unit for the years 1990-2012.
- 1A2f: Cement industry; values for shares of fossil C in the alternative fuels solvents, plastics and special waste/sawdust mixes that have previously been rounded are now not being rounded anymore in the calculation for the EF CO_2. This leads to slightly different EF for these fuels.
- 1A2f: the activity data (tiles) of 1A2f Brick and tile production for 2012 have been corrected due to a data mistake in last year's submission.
- 1A2f: the AD of animal grease have been corrected in 1A2f Brick and tile production for 2000-2012 due to a mistake in last year's submission.
- 1A2f: the AD (gas oil, liquefied petroleum gas) of 1A2f Rockwool production have been revised for 1990-2000 based on a correction in the split between the two fuels in 1990. This results in revised interpolated values for 1991 to 2000 as well.
- 1A2f: the AD of animal grease have been corrected in 1A2f Brick and tile production for 2000-2012 due to a mistake in last year's submission.
- 1A2f: the AD of gas oil consumption have been revised in 1A2f Fine ceramics production for 2003-2012 based on new available data from industry.
- 1A2f: the EF of CO and NO_x from 1A2f Container glass production have been revised for 2006-2012 based on new data from air pollution control measurements.
- 1A2f: the SO_x EF from 1A2f Container glass production has been revised for 2011-2012 based on new data from air pollution control measurements.
- 1A2f: the EF of NO_x and NMVOC from 1A2f Lime production have been revised for 1990-2012 based on new data from air pollution control measurements.
- 1A2f: the EF of SO_x from 1A2f Lime production has been revised for 1994-2012 based on recent data from air pollution control measurements.
- 1A2f: the EF of NOx from 1A2f Mineralwool production has been revised for 2000-2012 based on air pollution control measurements
- 1A3b: New calorific values for gasoline, diesel, gas oil and kerosene based on new measurements for the year 2013. Therefore new CO_2 emission factor timeseries were generated. Now the emission factors are constant from 1990-1998 reflecting the old mesurements and interpolated between 1998-2013 to the new measurements for 2013.
- 1A3b: for source category Fuel tourism and statistical differences, emission factors of all GHG have been recalculated due to the model revision for the entire time series 1990-2013.
- 1A3b: Since a small change occurred in the gasoline consumption in Liechtenstein for 2001-2011, small changes in the activity data for Fuel tourism and statistical differences resulted in Switzerland.
- 1A4: the AD (gas oil, natural gas) of 1A4ci Grass drying have been revised for 2012. The interpolated values of 2012 have changed due to updated real data for 2013.

- 1A4: in the past consumption of biogas did not include statistical difference to the swiss overall energy statistic. This difference is now included in the calculation of activities for boilers in 1A4c.
- 1A5a: New calorific values for gasoline, diesel, gas oil and kerosene based on new measurements for the year 2013. Therefore new CO_2 emission factor timeseries were generated. Now the emission factors are constant from 1990-1998 with the old measurements and interpolated between 1998-2013 to the new measurements for 2013.

2 Industrial processes and other product use

- 2A1 Cement production: AD and EF of cement production (blasting operations) are now related to tons of clinker, and not cement as it was before. Therefore all data from 1990-2012 have been converted to this unit.
- The EF of CO_2 and CO for cement production (blasting operations) have been corrected. It is taken from the Environmental Enforcement: Handbook, Emission Factors for Stationary Sources (SAEFL 2000).
- 2A3 Container glass production: The EF of geogenic CO_2 has been revised for 2005-2012. From 2005 onwards the EF values base now on effective carbonate contents in the raw material instead of cullet ratios wich are still used for the years 1990-2004.
- 2A3 Glass production (speciality tableware): The EF of geogenic CO_2 has been revised for 2012 based on the effective cullet ratio.
- 2A4a Brick and tile production: The AD for 2012 have been corrected due to a mistake in last year's submission.
- 2A4d Rockwool production: The EF of geogenic CO_2 has been revised for the entire time series based on new available data of the carbonate content in the raw material for the years 2005-2011.
- 2A4d Other process uses of carbonates: In source category 2A4d Other process uses of carbonates the CO_2 emissions from the use of ammonium bicarbonate are newly included in the inventory for the entire time period.
- 2B10 Other: CO_2 emissions from two new source categories 2B10 niacin production and 2B10 limestone pit are included in the inventory for the entire time period 1990-2013.
- 2B10 Other: The SO_2 emission factor from 2B10 Sulphuric acid production has been revised for 1990-2009 based on the updated EF value for 2013.
- 2D1 Lubricant use: CO2 emissions are newly reported in the inventory for the entire time series 1990-2013 according to the 2006 IPCC Guidelines.
- 2D2 Paraffin wax use: CO2 emissions are newly reported in the inventory for the entire time series 1990-2013 according to the 2006 IPCC Guidelines.
- 2D3a Coating applications: The AD and NMVOC EF for 2D3a (2D3d NFR) Paint application, construction and 2D3a (2D3d NFR) Paint application, wood have been updated for 2013 resulting in revised interpolated values for 2011 and 2012.
- 2D3a Coating applications: The two source categories 2D3a (2D3d NFR) Industrial paint application, other and 2D3a (2D3d NFR) Non-industrial paint application, other have been combined in one source category 2D3a (2D3d NFR) Paint application, industrial & non-industrial resulting in small rounding changes in the NMVOC EF values

between 2001 and 2012. Due to the updated AD for 2013 also the interpolated AD values for 2011 and 2012 have been revised.

- 2D3a Chemical products, manufacture and processing (2D3g NFR): The AD and NMVOC EF for 2D3a (2D3g NFR) Polyurethane processing have been updated for 2008–2012, respectively, resulting in revised interpolated EF values for 2008–2011 as well.
- 2D3a Chemical products, manufacture and processing (2D3g NFR): The AD and NMVOC EF for 2D3a (2D3g NFR) Ink production have been updated for 2013 resulting in revised interpolated values for 2011 and 2012.
- 2D3a Chemical products, manufacture and processing (2D3g NFR): The NMVOC EF for 2D3a (2D3g NFR) Polystyrene processing has been updated for 2012 resulting in revised interpolated EF values for 2008-2011 as well.
- 2D3c Asphalt roofing: The NMVOC EF for 2D3c Asphalt roofing has been updated for 2013 resulting in revised interpolated EF values for 2011 and 2012.
- 2D3d Urea use in SCR catalysts of diesel engines: CO_2 emissions are newly reported in the inventory for the entire time series 1990-2013 according to the CRF templates.
- 2E Electronics industry: IPCC Guidelines (2006) introduce a new categorization for applications in the electronics industry, with new model approaches for sub-categories and process gas specific transmission rates (fomer evaluations under 2F7 Semiconductor and partly under 2F5 Solvents and 2F9 Other).
- 2F Product uses as substitutes for ODS: The former category 2F Consumption of HFC, PFC and SF_6 was split into the new categories 2F Product uses as substitutes for ODS, 2E Electronics industry, 2G Other product manufacture and use.
- 2F1 Refrigeration and air conditioning: Optimizations of model caclulations including lower charge of equipment in mobile air conditioning, new application tumble dryers, included under stationary air conditioning, general harmonziations of model calculations, changes in split of imported in bulk refrigerant on different applications.
- 2F2 Foam blowing agents: New model approach for unknown application (IPCC 2006 recommendation Gamlen model, changes of lifetime and losses, disposal AD so far not relevant).
- 2F5 Solvents: Shift of substances to other applications. HFC-134a and HFC-245fa to 2F4 Aerosols (IPCC 2006: aerosol solvents included unter arosols), shift of PFCs to 2E Electronics industry and 2G2 Other PFC and SF_6 use.
- 2G2 SF_6 and PFCs from other product use: Improvement of model calculations of PFC emissions (former evaluation under 2F9 Other). Confidential data (Carbotech 2015).
- 2G4 Other: Improvement of model calculations of HFC emissions (former evaluation under 2F9 Other). Confidential data (Carbotech 2015).
- 2G4 Other: The NMVOC EF for 2G4 (2D3a NFR) Household cleaning agents has been updated for 2013 resulting in revised interpolated EF values for 2011 and 2012.
- 2G4 Other: The NMVOC EF for 2G4 (2D3a NFR) Domestic use of spray cans has been updated for 2013 resulting in revised interpolated EF values between 2008 and 2012.
- 2G4 Other: The source category 2G4 (2D3h NFR) Printing has been split into 2G4 Printing and 2G4 Package printing resulting in small rounding changes in the NMVOC EF values for the entire time series 1990-2012. The AD have been updated for 2013 yielding revised interpolated values for 2011 and 2012.

- 2G4 Other: The NMVOC EF for 2G4 (2D3i NFR) Removal of paint and lacquer has been updated for 2013 resulting in revised interpolated EF values for 2011 and 2012.
- 2G4 Other: For 2G4 (2D3i NFR) Production of cosmetics the AD has been updated for 2013 resulting in revised interpolated values for 2011 and 2012 whereas the NMVOC EF has been revised for the entire time series 1990-2012.
- 2G4 Other: The AD of 2G4 (2G NFR) fireworks has been revised from 2001 onwards. AD is now based on the fedpol statistics of pyrotechnics (FEDPOL 2014).
- 2G4 Other: The EF of NMVOC from 2G4 (2G NFR) Mineralwool enduction has been revised for 2009-2012 based on air pollution control measurements.
- 2G4 Other: The AD and NMVOC EF for 2G4 (2G NFR) Commercial and industrial use of cleaning agents have been updated for 2013 resulting in revised interpolated values for 2011 and 2012.
- 2H1 Pulp and paper: The AD of 2H1 Fibre board production for 2012 has been corrected due to a mistake in last year's submission.

3 Agriculture

- 3A, B, D: Several new livestock categories are reported for the first time in the 2015 submission (buffalo, camels, deer, rabbits, livestock NCAC).
- 3A, B: Gross energy intake of mature dairy cattle was recalculated with a new more detailed model.
- 3A, B: Milk yield of mature dairy cattle in the year 2012 was slightly revised due to an update of the provisional value of the Swiss Farmers Union.
- 3A, B: Preliminary estimates for energy requirements for sheep, swine, goats and poultry for the years 2010-2012 were revised due to an updated dataset received from the Swiss Farmers Union.
- 3A: All methane conversion rates (Y_m) were revised in the course of the switch to the 2006 IPCC Guidelines.
- 3B: VS-excretion was recalculated according to the new estimates of gross energy intake and the respective parameters in the 2006 IPCC Guidelines.
- 3B: MCF-values were recalculated according to the 2006 IPCC Guidelines and in order to better reflect Swiss specific manure management conditions (especially for liquid/slurry systems). In the course of this recalculation the assessment of emissions from anaerobic digesters was revised and harmonized with the respective estimates in the waste sector.
- 3B, D: The nitrogen excretion rate of mature dairy cattle was revised using the Agroscope feeding model.
- 3B: New emission factors for NO_x volatilisation from Manure management were adopted.
- 3B: Emission factors for direct N_2O emissions from Manure management were adjusted to the 2006 IPCC Guidelines. Additionally the emission factor for indirect N_2O emissions from Manure management was revised.
- 3D: Crop yield data for the years 2011 and 2012 were revised due to some updates from the Swiss Farmers Union.

- 3D: Some new crop cultures were introduced to estimate nitrogen inputs from crop residues (millet, lupines, oil squash, oil hemp, oil flax, hops and medicinal plants and herbs).
- 3D: The nitrogen-flow-model was revised according to the 2006 IPCC Guidelines.
- 3D: Emission factors for N_2O emissions from N inputs (EF_1) and N_2O emissions from urine and dung N deposited on pasture, range and paddock by grazing animals (EF_3) were adapted to the new IPCC default values.
- 3D: The area of agricultural land and the alpine area used to estimate NH_3 volatilisation from the vegetation cover was slightly revised.
- 3D: NO_x volatilisation from applied N-fertilisers was revised adopting more detailed literature values.
- 3D: The emission factor for indirect N_2O emissions from atmospheric deposition of N was revised (EF_4).
- 3D: $Frac_{LEACH}$ was recalculated due to new model estimates from Hürdler et al. (2015).
- 3D: The emission factor for indirect N_2O emissions from leaching and run-off (EF_5) was adapted to the 2006 IPCC Guidelines.

4 Land Use, Land-Use change and Forestry (including HWP)

- 4A: New values of stocks, gains and losses of living biomass were derived from most recent NFI 4b data. Implied emission factors for productive forests (CC12) in the period 2006-2012 were affected.
- 4A: Carbon stock changes in mineral soils, dead wood and litter for productive forests (CC12) were recalculated for all years due to improvements in the application of the Yasso07 model.
- 4A: The emission factor for organic soils on forest land was changed from -0.68 to -2.6 t C ha^{-1} yr^{-1}.
- 4A and 4C: The carbon stocks in living biomass of brush forests were revised based on Düggelin and Abegg (2011). As a consequence, carbon stocks of the combination categories CC13, CC32, CC34 and CC36 were adjusted for all years.
- 4B: On cropland, the provisional value of carbon stock in living biomass was revised for the year 2012. The carbon stock change in living biomass was recalculated for 1990.
- 4(II): N_2O emissions from drained organic soils are reported for the first time on forest land and unproductive wetlands.
- 4(III): N_2O emissions from mineralisation of organic matter in mineral soils due to land-use changes are reported for the first time for forest land, grassland, wetlands, settlements and other land. In former submissions, only land converted to cropland was reported. The new default emission factor was applied.
- 4(IV): Indirect N_2O emissions due to leaching and run-off of nitrogen are reported for the first time.
- 4G: Net CO_2 emissions and removals from harvested wood products (HWP) are reported for the first time.
- CO_2 emissions from agricultural lime application have been relocated to the agriculture sector.

5 Waste

- 5A Solid Waste Disposal: Due to the recalculation of the C-content of municipal solid waste and the changes in the shares of fossil C in waste, the EF for open burning on solid waste disposal sites is changed acccordingly.
- 5A Solid Waste Disposal: As an outcome of UNFCC review of inventory 2014 Switzerland had to set the AD of biogas flared to zero (1990-2013) until there is a better estimate of the amount of gas flared on Swiss disposal sites.
- 5B Biological Treatment of Solid Waste: Values of the amounts of biogas used and fed into the gas system have changed for the years 2011 and 2012 in the Swiss renewable energy statistics leading to changes in activity data of industrial biogas facilities.
- 5B Biological Treatment of Solid Waste:The amount of digestate used by agricultural biogas facilities has been corrected due to a plausibility check leading to changes in the activity data of industrial biogas facilities.
- 5C Incineration and Open Burning of Waste: Due to the recalculation of the C-content of municipal solid waste and the changes in the shares of fossil C in waste, the EF for illgegal waste burning is changed acccordingly.
- 5C Incineration and Open Burning of Waste: The amount sewage sludge burnt in SSIP is caclulated based on the total amount of sewage sludge and the amount burnt in MSWIP and in the cement industry for the years 2010 onwards (in the previous submission the amount was interpolated). This leads to changed AD starting from 2007 onwards.
- 5D Wastewater Treatment and Discharge: The methods to calculate emissions from wastewater have been changed according to the 2006 IPCC Guidelines (IPCC 2006). Time series of CH4 and N2O emissions have fully been recalculated.

6 Other

- No recalculations for this submission.

7 Indirect CO_2 and Nitrous Oxide Emissions

- No recalculations for this submission.

KP- LULUCF Inventory

A recalculation of the years 2008, 2009, 2010, 2011 and 2012 was carried out. The methodological improvements affect the activities reported under KP Art. 3.3 as well as under KP Art. 3.4. The improvements are described in detail in Chapter 6.4.5 (Recalculations 4A LULUCF Forest Land) and in Chapter 11.3.1.4 (Kyoto specific recalculations).

- The calculation of carbon stock changes in living biomass after Afforestation is harmonized between reporting under the UNFCCC and accounting under the KP by using average emission factors.
- Net CO_2 emissions and removals from harvested wood products (HWP) are reported for the first time.
- N_2O emissions from mineralisation of organic matter in mineral forest soils due to land-use changes are reported for the first time.

10.2 Implications for Emission Levels

Table 10-3 shows the recalculation results for the base year 1990. It results in a increase of the total emissions in CO_2 equivalents (without emissions/removals from CO_2 from LULUCF) of 308.97 kt CO_2 eq. This corresponds to a increase of the latest submission compared to the previous submission (2014) by 0.58% of the national total. If the LULUCF sector is included, there is an increase of 496.29 kt CO_2 eq (0.97%).

Table 10-3 Overview of implications of recalculations on 1990 data. Emissions are shown before the recalculation according to the previous submission in 2014 "Prev." (FOEN 2014) and after the recalculation according to the present submission "Latest". The differences "Differ." are defined as latest minus previous submission.

Recalculation	**CO_2**			**CH_4**			**N_2O**			**Sum (CO_2, CH_4 and N_2O)**		
Emissions for 1990	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.
Source and Sink Categories	CO_2 equivalent (kt)									CO_2 equivalent (kt)		
1. Energy	41'199	40'814	-384.90	507.1	597.0	89.93	304.7	297.0	-7.72	42'011	41'708	-302.68
2. IPPU	3'366	3'095	-271.12	1.5	2.0	0.46	178.3	171.0	-7.27	3'546	3'268	-277.93
3. Agriculture	0	49	49.00	3'307.1	4'420.0	1'112.94	2'785.0	2'244.0	-541.04	6'092	6'713	620.90
4 LULUCF excl. HWP	-1'962	-1'857	105.2	30.3	36.0	5.67	10.5	87.0	76.46	-1'921	-1'734	187.31
5. Waste	63	63	-0.33	821.9	1'150.0	328.06	209.6	142.0	-67.61	1'095	1'355	260.12
6 Other	11	11	0.00	0.6	0.0	-0.55	0.6	0.6	-0.02	12	12	-0.58
Sum (without F-gases)	42'677	42'175	-502.2	4'668	6'205	1'536.50	3'488	2'942	-547.20	50'834	51'322	487.14

Recalculation	**HFC**			**PFC**			**SF6**			**Sum (synthetic gases)**		
Emissions for 1990	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.
Source and Sink Categories	CO_2 equivalent (kt)									CO_2 equivalent (kt)		
2 Ind. Processes (only syn. gases)	0.02	0.00	-0.02	100.2	116.0	15.79	143.6	137.0	-6.62	243.85	253.00	9.15

Recalculation		**Sum (all gases)**		
Emissions for 1990		Prev.	Latest	Differ.
Source and Sink Categories		CO_2 equivalent (kt)		
Total CO_2 eq Em. with LULUCF		**51'078**	**51'575**	**496.29**
		100%	100.97%	0.97%
Total CO_2 eq Em. without LULUCF		**53'000**	**53'309**	**308.97**
		100%	100.58%	0.58%

For 2012, the recalculation results in a increase of the total emissions in CO_2 equivalents (without emissions/removals from LULUCF) of 129.05 kt CO_2 eq (see Table 10-4). This corresponds to an increase of 0.25% of the national total in the latest submission compared to the previous submission. If the LULUCF sector is included, a decrease of 184.5 kt CO_2 eq. (0.37%) results.

Table 10-4 Overview of implications of recalculations on 2012 data. Emissions are shown before the recalculation according to the previous submission in 2014 “Prev.” (FOEN 2014) and after the recalculation according to the present submission “Latest”. The differences “Differ.” are defined as latest minus previous submission.

Recalculation	**CO_2**			**CH_4**			**N_2O**			**Sum (CO_2, CH_4 and N_2O)**		
Emissions for 2012	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.
Source and Sink Categories	CO_2 equivalent (kt)									CO_2 equivalent (kt)		
1 Energy	41'000	39'994	-1'006.17	264.9	304.1	39.25	235.7	226.7	-9.05	41'501	40'525	-975.98
2 IPPU (without F-gases)	2'225	2'183	-42.47	2.4	2.8	0.46	98.2	94.4	-3.80	2'326	2'280	-45.81
3 Agriculture	0	41	41.36	3'143	4'039	895.44	2'395	1'935	-460.15	5'539	6'015	476.66
4 LULUCF excl. HWP	-1'142	-1'525	-383.44	9.5	11.0	1.55	3.7	72.0	68.33	-1'129	-1'442	-313.56
5 Waste	12	10	-2.34	307.1	805.1	498.04	291.7	197.4	-94.33	611	1'012	401.37
6 Other	13	13	0.00	0.6	0.6	0.03	0.6	0.6	-0.02	14	14	0.01
Sum (without F-gases)	42'109	40'716	-1'393	3'727	5'162	1'435	3'025	2'526	-499	48'862	48'404	-457.31

Recalculation	**HFC**			**PFC**			**SF6**			**Sum (synthetic gases)**		
Emissions for 2012	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.
Source and Sink Categories	CO_2 equivalent (kt)									CO_2 equivalent (kt)		
2 Ind. Processes (only syn. gases)	1'245.04	1'495.00	249.96	33.1	71.0	37.92	224.0	208.9	-15.07	1'502.10	1'774.91	272.81

Recalculation		**Sum (all gases)**		
Emissions for 2012		Prev.	Latest	Differ.
Source and Sink Categories		CO_2 equivalent (kt)		
Total CO_2 eq Em. with LULUCF		**50'364**	**50'179**	**-184.50**
		100%	99.63%	-0.37%
Total CO_2 eq Em. without LULUCF		**51'493**	**51'622**	**129.05**
		100%	100.25%	0.25%

10.3 Implications for Emissions Trends, including Time Series Consistency

Due to recalculations, the emission trend 1990–2012 reported in the present 2015 submission has slightly changed. Compared to 1990, 2012 emissions (national total without emissions/removals from LULUCF) showed a decrease of 2.84% before recalculation (previous submission). After recalculation, the decrease is slightly larger with a change 1990–2012 of 3.16% (latest submission) see Table 10-5.

Table 10-5 Change of the emission trend 1990–2012 due to recalculation. “Previous” refers to data reported in FOEN (2014), whereas “latest” refers to the present submission.

Recalculation	**1990**		**2012**		**change 2012/1990**	
Submission	previous	latest	previous	latest	previous	latest
Unit	CO_2 eq (Gg)				%	
Total excl. LULUCF	53'000	53'309	51'493	51'622	-2.84%	-3.16%

KP-LULUCF data for 2013, the first year of the second commitment period is submitted for the first time. A recacluation of the emissions of the timeseries 1990-2012 has been done based as described in Chapter 6.4.5 and 11.3.1.4.

All-time series in the present submission are consistent.

10.4 Planned Improvements, including in Response to the Review Process

For 1A the CH_4 and N_2O emission factors for stationary combustion will be reassessed for Submission 2016.

In 1A1 for N_2O emission factors from waste incineration it is planned to calculate a new value in submission 2017 based on the amounts of waste burnt in 2015. See documentation in EMIS 2015/1A1a Kehricht- und Sondermüllverbrennungsanlagen.

For non-road related source categories in 1A the consideration of the revised non-road model in data reporting is envisaged in next submission.

More detailed information on the decision to adopt a country-specific value for the carbon stock changes in organic soils for cropland and permanent grassland will be available from an ongoing study at Agroscope and will be incorporated in the next submission.

Information and references in combination with the expert judgement used to support the values reported in the Party's GHG inventory and reflect the realistic dimension for activities reported as afforestation in its national forest inventory will be available from the results of a Swiss study analyzing gross growth on afforestations.

For source category 5A a study is currently underway looking into ways to better quantify the amounts flared. Results are expected in the course of 2015 and will be implemented in the next NIR.

For KP-LULUCF the conducted and planned methodological improvements are described in Chapter 11.3.1.4 (Kyoto specific recalculations) and Chapter 6.4.5 (Recalculations LULUCF Forest Land).

For further planned improvements please refer to respective chapters "planned improvements" for each source category.

PART 2

11 KP-LULUCF

Switzerland will choose to account over the entire second commitment period for emissions and removals from activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol (FOEN 2015e). In addition to the mandatory submission of the inventory year 2013, data for the years 1999-2012 are available and shown in Switzerland’s NIR. Switzerland accounts for the mandatory activity Forest Management under Article 3, paragraph 4 of the Kyoto Protocol (FOEN 2015e). Switzerland applies the condition of “direct human-induced” in relation to Afforestation and Deforestation very strictly for both activities (see Chapter 11.1.3, FOEN 2010d, FOEN 2010h). Table 11-1 shows the activity coverage and the carbon pools reported for the mandatory activities under Article 3, paragraph 3 and for Forest Management under paragraph 4 of the Kyoto Protocol. The areas and change in areas between the previous and the current inventory year are shown in Table 11-2. Table 11-3 summarizes the results of the KCA for LULUCF activities under the Kyoto Protocol.

Table 11-1: NIR1 – Summary-Table.

CRF-Table not yet availalbe.

Table 11-2 NIR 2 – Land Transition Matrix Inventory Year 2013: the total Swiss area amounts too 4'128.42 kha. A time series of the total values for Article 3.3 and Article 3.4 activities is displayed in Table 11-5.

CRF-Table not yet availalbe.

Table 11-3: NIR 3 – Summary Overview for Key Categories for LULUCF Activities under the KP in 2013. A detailed description of the KCA for Article 3.3 and 3.4 activities is given in Chapter 11.6.1.

CRF-Table not yet availalbe.

An overview of net CO_2 eq emissions and removals of activities under Article 3, paragraph 3 and Forest Management under Article 3, paragraph 4 of the Kyoto Protocol is shown in Figure 11-1 and Table 11-4. Differences in the annual emissions from Deforestation can mainly be attributed to the changes in the area of Deforestations (see Table 11-5 and Figure 11-2). Year-to-year differences in removals from Afforestations are mainly due to changes in the afforested area (see Table 11-5). Another relevant factor is the application of an exponential growth curve for Afforestations younger than 20 years (see Chapter 11.3.1.1; Figure 11-2; see Table 6-25). Fluctuations in the contribution of Forest Management can mainly be explained by changes in the losses of living biomass, dead wood and litter, whereas fluctuations in the area of managed forest are moderate (see Table 11-5). In 2001 and 2002, Forest Management was a small source of CO_2 eq due to the damages caused by the storm Lothar. Fluctuations in the HWP-pool can mainly be attributed to changes in the production of sawnwood (see Chapter 6.11 and Table 6-35), which is strongly linked with the domestic harvesting rate.

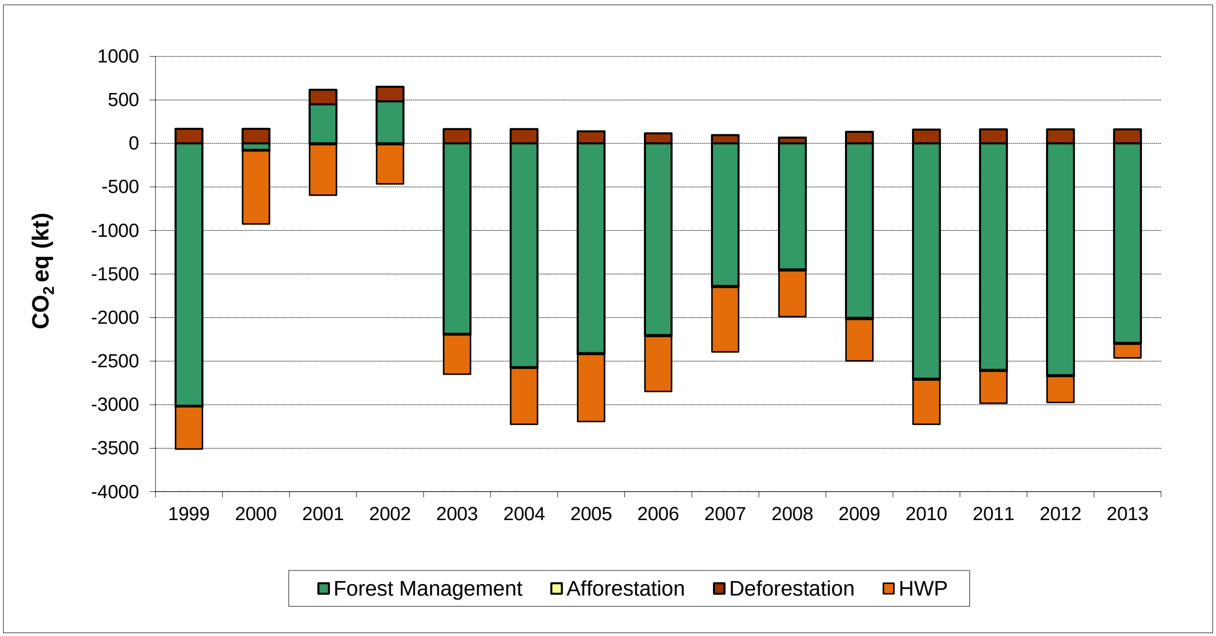


Figure 11-1 CO_2 eq emissions (positive sign) and removals (negative sign) from Afforestation (too small to be distinguishable) and Deforestation under Article 3, paragraph 3 and Forest Management and HWP under Article 3, paragraph 4, 1999-2013.

Table 11-4 Overview on net CO_2 equivalent emissions (positive sign) and removals (negative sign) for activities under Article 3, paragraph 3 and Forest Management (FM) under Article 3, paragraph 4 of the Kyoto Protocol, 1999-2013. Used abreveations explained in Chapter 6.1.3.2; C_{l_ag}: C above-ground living biomass; C_{l_bg}: C below-ground living biomass; C_h: C in litter, C_{s_md}: C in dead wood, C_{s_m}: C in mineral soil; C_{s_o}: C in organic soil.

Greenhouse gas source and sink activities	1999	2000	2001	2002	2003	2004	2005	2006
	Net CO_2 equivalent emissions/removals (kt CO_2 eq)							
Article 3.3 activities	**156.42**	**155.78**	**154.64**	**153.42**	**152.21**	**151.32**	**124.96**	**102.44**
A.1. Afforestation and Reforestation	-10.99	-11.42	-11.86	-12.29	-12.73	-13.16	-13.89	-14.49
Afforestation ≤ 20 y	-10.99	-11.42	-11.86	-12.29	-12.73	-13.16	-13.89	-14.49
Afforestation > 20 y	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A.2. Deforestation	167.41	167.20	166.49	165.71	164.94	164.48	138.85	116.92
Article 3.4 activities	**-3013.06**	**-74.89**	**450.67**	**484.87**	**-2187.34**	**-2569.04**	**-2407.81**	**-2200.73**
B.1. Forest Management incl. biomass burning	-3013.06	-74.89	450.67	484.87	-2187.34	-2569.04	-2407.81	-2200.73
gainC_{l_ag}	-9698.84	-9705.57	-9712.30	-9719.03	-9725.76	-9732.50	-9747.02	-9836.02
gainC_{l_bg}	-2757.69	-2760.25	-2762.81	-2765.37	-2767.93	-2770.49	-2780.04	-2808.99
lossC_{l_ag}	7758.49	10051.46	10371.07	10243.35	8273.15	8004.26	8375.33	8472.02
lossC_{l_bg}	2253.94	2849.44	2927.38	2896.28	2394.55	2321.72	2428.41	2409.11
changeC_h	-324.83	-266.67	-169.85	-34.73	-204.30	-211.57	-455.64	-230.67
changeC_d	-280.50	-280.49	-239.68	-190.84	-219.72	-215.71	-264.99	-244.48
changeC_{s_m}	-1.82	-2.35	-2.74	-2.97	-3.19	-3.56	-4.06	-4.61
changeC_{s_o}	37.73	37.75	37.77	37.78	37.80	37.82	37.85	37.90
sum FM exl. biom. burning	-3013.51	-76.68	448.83	464.47	-2215.40	-2570.03	-2410.15	-2205.75
biom. burning	0.45	1.79	1.84	20.40	28.06	1.00	2.34	5.03
B.2. Cropland Management	NA	NA	NA	NA	NA	NA	NA	NA
B.3. Grazing Land Management	NA	NA	NA	NA	NA	NA	NA	NA
B.4. Revegetation	NA	NA	NA	NA	NA	NA	NA	NA
C. HWP	-485.54	-837.52	-582.32	-453.53	-448.75	-644.41	-771.69	-633.43

Greenhouse gas source and sink activities	2007	2008	2009	2010	2011	2012	2013	2014
	Net CO_2 equivalent emissions/removals (kt CO_2 eq)							
Article 3.3 activities	**80.00**	**53.04**	**117.45**	**145.20**	**146.21**	**147.14**	**147.60**	
A.1. Afforestation and Reforestation	-15.04	-15.53	-15.96	-15.34	-14.78	-14.29	-14.32	
Afforestation ≤ 20 y	-15.04	-15.53	-15.96	-14.56	-13.24	-11.94	-10.79	
Afforestation > 20 y	0.00	0.00	0.00	-0.79	-1.54	-2.36	-3.52	
A.2. Deforestation	95.04	68.56	133.42	160.55	160.99	161.43	161.92	
Article 3.4 activities	**-1636.91**	**-1447.67**	**-2003.56**	**-2701.27**	**-2600.01**	**-2660.79**	**-2290.79**	
B.1. Forest Management incl. biomass burning	-1636.91	-1447.67	-2003.56	-2701.27	-2600.01	-2660.79	-2290.79	
gainC_{l_ag}	-9951.58	-10055.53	-10067.57	-10071.85	-10076.08	-10080.31	-10084.47	
gainC_{l_bg}	-2845.83	-2879.37	-2883.61	-2885.61	-2887.44	-2889.28	-2891.10	
lossC_{l_ag}	8807.35	8856.67	8481.49	8251.90	8204.50	8118.54	8139.59	
lossC_{l_bg}	2512.57	2543.80	2454.51	2404.90	2400.63	2380.71	2582.65	
changeC_h	33.07	307.28	272.44	-55.08	48.35	72.92	175.68	
changeC_d	-237.28	-256.51	-296.59	-380.53	-331.87	-298.01	-247.89	
changeC_{s_m}	-4.79	-4.63	-4.32	-4.25	-4.42	-4.48	-4.46	
changeC_{s_o}	37.94	37.97	38.00	38.00	38.01	38.02	38.03	
sum FM exl. biom. burning	-1648.55	-1450.31	-2005.65	-2702.51	-2608.32	-2661.89	-2291.97	
biom. burning	11.64	2.64	2.09	1.24	8.31	1.09	1.18	
B.2. Cropland Management	NA	NA	NA	NA	NA	NA	NA	
B.3. Grazing Land Management	NA	NA	NA	NA	NA	NA	NA	
B.4. Revegetation	NA	NA	NA	NA	NA	NA	NA	
C. HWP	-741.76	-524.55	-479.46	-509.57	-369.81	-299.55	-158.15	

The KP-CRF-table “Information table on accounting for activities under Article 3, paragraph 3 and 4 of the Kyoto Protocol” gives an overview of the CO_2 eq emissions and removals from Afforestation and Deforestation under Article 3, paragraph 3 and Forest Management under Article 3, paragraph 4 and also provides information on the extent to which GHG removals by sinks offsets the debit incurred under Article 3.3.

- In 2013, Forest Management in Switzerland caused removals of -2290.79 kt CO_2 eq. The debit incurred from activities under Article 3.3 is 147.60 kt CO_2 eq.

11.1 General Information

The inventory datasets on which the calculations are based (Swiss Land Use Statistics AREA and National Forest Inventory NFI) are described in Chapters 6.2, 6.3 and 6.4.2.1, respectively.

Methodological issues and assumptions concerning the calculation of activity data and emission factors used for the reporting under Article 3, paragraphs 3 and 4 of the Kyoto Protocol, follow the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006) as described in Chapter 6.4.2 and the KP-Supplement (IPCC 2014).

11.1.1 Definition of Forest and any other Criteria

The forest definition used under the Kyoto Protocol is defined in Switzerland's first Initial Report (FOEN 2006h, Sect. E) and is still valid for the second commitment period (FOEN 2015e; see also Chapter 6.4.1 in this submission). Forest is defined as a minimum area of land of 0.0625 ha with crown cover of at least 20% and a minimum width of 25 m. The minimum height of the dominant trees must be 3 m or have the potential to reach 3 m at maturity in situ. The selected values are also listed in KP LULUCF Table NIR1 (see Table 11-1).

Some source categories were explicitely excluded from the category “Forest Land”, although they may partly fulfil the requirements of the Swiss forest definition used under the Kyoto Protocol (see Chapter 6.2.1, Table 6-6; Chapter 6.4.1 and FOEN 2006h section E). Those are:

- Vineyards, Low-Stem Orchards, Tree nurseries, Copses and Orchards in the land-use category “Grassland”;
- Cemeteries and public parks in the land-use category “Settlements”.

11.1.2 Elected Activities under Article 3, Paragraph 4, of the Kyoto Protocol

Switzerland will account for the mandatory activity Forest Management under Article 3, paragraph 4 of the Kyoto Protocol (FOEN 2015e). In accordance with Annex I to Decision 2/CMP.7 (Annex I, Para 13), credits from Forest Management are capped in the second commitment period. For Switzerland, the cap amounts to 3.5% of the 1990 emissions (excluding LULUCF).

11.1.3 Description of how the Definitions of each Activity under Article 3.3 and each elected Activity under Article 3.4 have been implemented and applied consistently over Time

The Swiss definitions of Afforestation, Deforestation and Forest Management are published in Switzerland's Initial Report (see FOEN 2006h, Sect. E and F). These definitions are still valid for the second commitment period (FOEN 2015e). Switzerland applies the condition of “direct human-induced” in relation to Afforestation and Deforestation very strictly for both activities (see FOEN 2010d, FOEN 2010h).

Afforestation

Afforestation is the conversion to forest of an area not fulfilling the definition of forest for a period of at least 50 years if the definition of forest in terms of minimum area (625 m^2) is fulfilled, and the conversion is a direct human-induced activity.

Natural forest regeneration following the abandonment of subalpine pastures is not considered to be a direct human-induced activity. Only Afforestations which can clearly be attributed as direct human-induced from aerial photographs (SFSO 2014; see also Chapter 6.3.1) are considered as Afforestation. Examples of direct human-induced Afforestations are shown in FOEN (2010h).

Deforestation

Deforestation is the permanent conversion of areas fulfilling the definition of forest in terms of minimum forest area (625 m^2) to areas not fulfilling the definition of forest as a consequence of direct human influence.

Temporary removals of (cluster of) trees (e.g. for the construction of high-voltage power lines, cable-car and powerlines, maintenance roads along railway lines and highways are not reported as Deforestation under the Kyoto Protocol because in those cases the forest stand has to be re-established. In the NFI methodology (Brändli 2010: 91) “forest aisles” under power lines are explicitly classified as forests. These forest aisles underlie however a specific management, i.e. maximum tree height is limited to a certain height. The NFI dataset thus covers such areas with a specific Forest Management practice.

After approximately 12 years (see Chapter 6.3.1) it is possible to check if deforestations or other land-use changes have been correctly classified. Sigmaplan (2012a) screened the classification of all land-use changes classified as Deforestation under the Kyoto Protocol. They found that 86% of all these Kyoto Deforestations are still deforested after 20 years, whereas 14% of these Kyoto Deforestations were in fact removals of crown coverage limited in time and should be classified as "management interventions" rather than as real land-use changes. As no reclassification was done, the area of Deforestations reported under KP Art. 3.3 is in fact a slight overestimation. Accordingly, emissions are overestimated since implied emission factors for Deforestations are higher than for Forest Management (see Table 4(KP-I)A.2 for Deforestations and Table 4(KP-I)B.1 for Forest Management).

Reforestation

Reforestation does not occur in Switzerland (FOEN 2006h, Sect. E; see also Chapter 11.4.1).

Forest management

Forest Management includes all activities serving the purpose of fulfilling the Federal Law on Forests (Swiss Confederation 1991, Art. 1c), i.e. the obligation to conserve forests and to ensure forest functions – such as wood production, protection against natural hazards, preservation of biodiversity, purification of drinking water and maintenance of recreational value – in a sustainable manner.

11.1.4 Description of Precedence Conditions and/or Hierarchy among 3.4. Activities and how they have been consistently applied in determining how Land was classified.

Since Switzerland will only account for Forest Management from the activities of Article 3, paragraph 4 of the Kyoto Protocol, the hierarchy among 3.4 activities does not affect Swiss reporting.

11.2 Land-related Information

11.2.1 Spatial Assessment Unit used for determining the Area of the units of Land

The spatial assessment unit for the submission of the KP LULUCF tables covers the entire territory of Switzerland, i.e. 4'128.42 kha (see Table 11-2).

All activity data for reporting the activities under the Kyoto Protocol are retrieved from the Swiss Land Use Statistics (SFSO 2014; see also Chapter 6.3.1). The Swiss Land Use Statistics AREA (SFSO 2006a) uses a georeferenced sample grid with a grid size of 100 m by 100 m. To each grid point a specific combination category (see Table 6-2) is assigned.

11.2.2 Methodology used to develop the Land Transition Matrix

The methodology used to develop the land transition matrix is described in detail in Chapter 6.2.3.

11.2.3 Maps / Database to identify the geographical Locations and the system of Identification Codes for the geographical Locations

All Afforestations and Deforestations are accounted for under Article 3, paragraph 3 and are not reported under Forest Management under Article 3, paragraph 4. Afforestations older than the conversion period of 20 years, are still reported under Afforestations: CRF-table 4(KP-I)A.1. The calculation of changes in carbon stocks is described in Chapter 11.3.1.1. The changes in areas between the activities under Article 3, paragraph 3 and Article 3, paragraph 4 are listed in KP-Table NIR2 (see Table 11-2).

Forest areas under Forest Management are subdivided into productive forests (CC12) and unproductive forests (CC13; for a description see Chapter 6.4.2.9). Productive forests in Switzerland reveal a high heterogeneity in terms of elevation, growth conditions and tree species composition (see Chapter 6.2.2 and Figure 6-3). Therefore, Switzerland has been stratified into five National Forestry Inventory production regions (L1: Jura, L2: Central Plateau, L3: Pre-Alps, L4: Alps, L5: Southern Alps), three altitudinal zones (Z1: <601 m, Z2: 601-1200 m, Z3: >1200 m) and two soil types (mineral soils and organic soils). In the KP CRF-tables, the stratification of the activity data into production region (L) and altitudinal level (Z) is indicated in the column “Subdivision”.

Area reported under Afforestation, Deforestation and Forest Management

AREA data allow to clearly separate between the land areas subject to a specific activity. Absolute and cumulated activity data of Afforestations, Deforestations and forests under Forest Management are listed in Table 11-5. The total Swiss area remains constant and amounts to 4'128.42 kha.

Table 11-5 Activity data for activities under Article 3, paragraphs 3 and 4, 1990-2013. Afforestation, Deforestation data and values depicting the area of Forest Management are derived from the Swiss Land Use Statistics (AREA) (derived from SFSO 2006a, 2014). See also KP-CRF-Table NIR2 (Table 11-2).

Year	Deforested area [kha]	Cumulated deforested area since 1990 [kha]	Afforested area [kha]	Cumulated afforested area since 1990 [kha]	Area Forest Management [kha]
1990	0.31	0.31	0.27	0.27	1178.82
1991	0.31	0.62	0.26	0.53	1181.97
1992	0.31	0.93	0.26	0.79	1185.14
1993	0.31	1.24	0.23	1.02	1188.18
1994	0.33	1.58	0.18	1.20	1191.08
1995	0.34	1.92	0.13	1.33	1193.86
1996	0.34	2.26	0.12	1.44	1196.36
1997	0.35	2.61	0.09	1.53	1198.84
1998	0.38	2.98	0.06	1.59	1201.10
1999	0.37	3.36	0.06	1.65	1203.32
2000	0.37	3.73	0.06	1.71	1205.53
2001	0.36	4.09	0.06	1.77	1207.75
2002	0.36	4.44	0.06	1.82	1209.96
2003	0.35	4.79	0.06	1.88	1212.18
2004	0.34	5.14	0.06	1.94	1214.39
2005	0.28	5.41	0.10	2.04	1217.30
2006	0.23	5.64	0.08	2.12	1220.14
2007	0.18	5.82	0.08	2.20	1223.01
2008	0.12	5.93	0.07	2.27	1226.24
2009	0.25	6.19	0.06	2.33	1229.15
2010	0.31	6.50	0.05	2.38	1230.41
2011	0.31	6.81	0.05	2.44	1231.53
2012	0.31	7.13	0.05	2.49	1232.66
2013	0.31	7.44	0.05	2.55	1233.78

Afforestation

Activity data for Afforestations are derived from the Swiss Land Use Statistics (AREA) (SFSO 2006a, 2014; see also Chapter 6.3.1). A detailed description of the identification of Afforestations fulfilling the Kyoto definition is provided in FOEN (2010h).

Deforestation

Data for Deforestations are derived from the Swiss Land Use Statistics (AREA). A detailed description of the identification of Deforestations under the Kyoto Protocol from the AREA dataset is given in FOEN (2010d) and Sigmaplan (2010a).

Not all changes from a forest combination category (Afforestation CC11, productive forest CC12 and unproductive forest CC13) to a non-forest combination category correspond to the definition of Deforestation according to the Kyoto Protocol Art. 3.3. The following criteria identify conversions from a forest combination category to a non-forest combination category, which are not classified as Deforestations under the Kyoto Protocol Art. 3.3 (FOEN 2010d):

1. Non-permanent conversions are due to Forest Management practices, natural dynamics or hazards:

- Tree loss is temporally limited: areas with loss of tree biomass, but where a change in land use cannot be identified. Natural regeneration, which is a common practice in Swiss Forest Management, is expected, but could not yet be recognized on the aerial photograph at the time the AREA survey (see Chapter 6.3.1) was conducted.

  Also, in the NFI methodology (Brändli 2010: 91) “forest aisles” under power lines are explicitly classified as forests (see also Chapter 11.1.3). Further, a study by Sigmaplan (2012a) showed that, although the aspect of "temporal limitiation" was considered when classifying Deforestations, at the end still 14% of these Kyoto Deforestations were in fact "short-term reduction of crown coverage" and should be classified as "management interventions" rather than as real land-use changes (see 11.1.3).
- Tree loss is spatially limited: conversion is caused by an alteration of the surrounding stand, but the change does not affect the tree cover at the sample point. This criterion also handles the case of a Swiss-specific silvo-pastoral system, namely grasslands with tree cover. It is very difficult for interpreters of aerial photographs to determine this land use/land cover correctly. In fact, these points could be attributed to two coequal land-use types: agricultural area (LU2XX) and forest area (LU3XX; cf. NIR Table 6-6). Land cover on these points is in general open forest (LC 44), linear woods (LC46) or cluster of trees (LC47; cf. NIR Table 6-6). When tree vegetation on these grasslands becomes denser over the years, land owners remove single trees every now and then. This management practice can lead to the fact that an interpreter of aerial photographs reclassifies the sample point into a different land-use type during a later survey (i.e. change from forest area LU3XX to agricultural area LU2XX), although in reality no LUC took place on these sites; and, moreover, all elements of the Kyoto forest definition are still fulfilled (see Table 2 in FOEN 2010d).

2. Conversions of combination categories (see Table 6-2 and Table 6-6) not meeting the definition of Deforestation as defined under the Kyoto Protocol and in Switzerland’s Initial Report (FOEN 2006h):

- Areas smaller than the minimum area of 625 m^2.

- Areas with a reduction in forest cover on the grid point but still fulfilling the Kyoto definition of Forest, i.e. having the potential to reach 3 m at maturity in situ.

3. No change in land use took place: reduction of tree cover without land-use change; former land use was mainly pasture

4. Tree loss is not human-induced: Conversion due to natural hazards and dynamics.

Implication for applying the above listed criteria for accounting under the Kyoto Protocol: One sample point represents an area of 1 ha; thus when a sample point is not classified as Kyoto deforestation, the corresponding area remains under FM. Changes in carbon stocks on these areas are estimated by the NFI (see NIR Chapter 7.3.4.1) and are reflected in the Implied Emission Factors in the CRF Tables and are thus completely accounted for.

Forest Management

Since all forests in Switzerland are subject to Forest Management, the area of managed forest corresponds to the forest area (see FOEN 2006h, Sect. E; FOEN 2015e) as derived from the Swiss Land Use Statistics (AREA; SFSO 2006a, 2014; see also Chapter 6.3). Changes in pools for the following geographical locations are reported:

- productive forest remaining productive forests (CC12 remaining)
- productive forest converted to unproductive forests (CC12 to CC13)
- unproductive forest remaining unproductive forests (CC13 remaining)
- unproductive forest converted to productive forests (CC13 to CC12).

Forest land is expanding in Switzerland (see Table 11-5). The Land-use change (Table 6-9) shows these conversions, mainly occurring on former grasslands (CC3X to CC12 or to CC13). The main reason is natural forest regeneration in the Alpine area due to the abandonment of land. Exemplary references, proving and discussing the fact that the area of Swiss forest is expanding, can be found in Rigling and Schaffer (2015), Brändli (2014), SWI (2009), and Gehrig-Fasel et al. (2007).

11.3 Activity-specific Information

11.3.1 Methods for Carbon Stock Change and GHG Emission and Removal estimates

11.3.1.1 Description of the Methodologies and the underlying Assumptions used

Emission factors for Afforestations, Deforestations and Forest Management were accounted for following the methodology described in Chapter 6.1.3.2. The methodological approach is based on Table 6-3 equations 6.1-6.8 and displayed in detail for each pool in Table 11-6. Annual values for carbon stocks and carbon stock changes in the pools of living biomass (for a description of seperation in above- and belowground living biomass see Chapter 6.4.2.6), dead wood, litter and soil carbon of Afforestations (CC11), productive forests (CC12) and unproductive forests (CC13) are displayed in Table 6-4, Table 6-19, Table 6-22 and Table 6-23. All working steps and data required to reproduce the calculation of emission factors the KP-CRF-Tables are summarized in FOEN (2015c).

Table 11-6 Application of the methodolgy described in equations 6.1-6.8 in Chapter 6.1.3.2 and in Table 6-3 for calculating carbon stock changes for the Kyoto activities Afforestations (CC11) younger than 20 years (≤ 20 yr) and older than 20 years (>20 yr), Deforestations (DEF) and Forest Management with the four geographic locations: CC12 remaining, CC13 remaining, conversions from CC12 to CC13 (FM CC1213) and conversions from CC13 to CC12 (FM CC1312). In the case of Deforestation (C1X to CC51), losses in soil carbon are accounted for by reducing the difference in soil carbon pools by 50% (see Chapter 6.8.2.2). A conversion time CT of 20 years is applied for all pools except for the loss of living biomass, litter and dead wood after Deforestation (CT=1 year). Subscripts used: l = living biomass, h = litter, d = dead wood, s = soil, i = spatial stratum, a = land-use-type after the conversion, b = land-use-type before the conversion. CC11 (Afforestation), CC12 (productive forests) and CC13 (unproductive forests) refer to the specific combination category (see Table 6-2).

	Living Biomass	Litter	Dead Wood	Soil
Afforestation CC11 ≤ 20 yr	gain-loss $gainC_{l,i,CC11}$ - $lossC_{l,i,CC11}$ = $gainC_{l,i,CC11}$ - 0 = $gainC_{l,i,CC11}$	stock-difference, CT=20 ($stockC_{h,i,CC11}$ - $stockC_{h,i,b}$)/CT = (0 - 0)/ 20 = 0	stock-difference, CT=20 ($stockC_{d, i,CC11}$ - $stockC_{d,i,b}$)/CT = (0 - 0)/20 = 0	stock-difference, CT=20 ($stockC_{s,i,CC11}$ - $stockC_{s,i,b}$)/CT
Afforestation CC11 > 20 yr	gain-loss $gainC_{l,i,CC12}$ - $lossC_{l,i,CC12}$	gain-loss $changeC_{h,i,CC12}$	gain-loss $changeC_{d,i,CC12}$	gain-loss $changeC_{s,i,CC12}$
Deforestation DEF	stock-difference, CT=1 ($stockC_{l,i,a}$- $stockC_{l,i,CC12}$)/CT	stock-difference, CT=1 ($stockC_{h,i,a}$ - $stockC_{h,i,CC12}$)/CT	stock-difference, CT=1 ($stockC_{d,i,a}$ - $stockC_{d,i,CC12}$)/CT	stock-difference, CT=20 C1X to CC51: 0.5($stockC_{s,i,CC51}$ - $stockC_{s,i,CC12}$)/CT C1X to other: ($stockC_{s,i,a}$ - $stockC_{s,i,CC12}$)/CT
CC12 remaining	gain-loss $gainC_{l,i,CC12}$ - $lossC_{l,i,CC12}$	gain-loss $changeC_{h,i,CC12}$	gain-loss $changeC_{d,i,CC12}$	gain-loss $changeC_{s,i,CC12}$
CC13 remaining	gain-loss $gainC_{l,i,CC13}$ - $lossC_{l,i,CC13}$ = 0	gain-loss $changeC_{h,i,CC13}$ = 0	gain-loss $changeC_{d,i,CC13}$ = 0	gain-loss $changeC_{s,i,CC13}$ = 0
CC12 to CC13	stock-difference, CT=20 ($stockC_{l,i,CC13}$ - $stockC_{l,i,CC12}$)/CT	stock-difference, CT=20 ($stockC_{h,i,CC13}$ - $stockC_{h,i,CC12}$)/CT = 0	stock-difference, CT=20 ($stockC_{d,i,CC13}$ - $stockC_{d,i,CC12}$)/CT = (0 - $stockC_{d,i,CC12)}$/20	stock-difference, CT=20 ($stockC_{s,i,CC13}$ - $stockC_{s,i,CC12}$)/CT = 0
CC13 to CC12	gain-loss $gainC_{l,i,CC12}$ - $lossC_{l,i,CC12}$	stock-difference, CT=20 ($stockC_{h,i,CC12}$ - $stockC_{h,i,CC13}$)/CT = 0	stock-difference, CT=20 ($stockC_{d,i,CC12}$ - $stockC_{d,i,CC13}$)/CT = $stockC_{d,i,CC12}$/20	stock-difference, CT=20 ($stockC_{s,i,CC12}$ - $stockC_{s,i,CC13}$)/CT = 0

Reforestation

Reforestation does not occur in Switzerland (FOEN 2006h, Sect. E).

Afforestation ≤ 20 years: Units of Land not harvested since the beginning of the Commitment Period

Most of the Afforestations occur on permanent grasslands CC31 and on settlements CC51 (see Table 6-9).

Living Biomass

- Gain in living biomass of Afforestations (gross growth) follows a exponential growth function. Values are available for three altitudinal levels (Table 6-25). The total gross growth of the cumulative afforested area was determined by multiplying the afforested area of a specific year with the mean value for growth (Table 6-26).

Litter and Dead Wood

- On grasslands and areas with settlements no litter and no dead wood is present, i.e. a carbon stock of zero is attributed (Table 6-4). Assuming neither dead wood nor litter on Afforestations, the difference in the carbon stocks of these pools is zero. This is a conservative estimate (in terms of IPCC good practice: IPCC 2006, Chapter 4.3.2), since there actually is a small pool of dead wood and litter under Afforestations. This conservative approach is confirmed in several studies (see Chapter 11.3.1.2).

Soil Carbon

- Organic soils: In the case of organic soils, emissions due to drainage are calculated as described in Chapter 6.4.2.11 and Chapter 11.3.1.2.
- Mineral soils: In the case of land-use conversions to Afforestations, the difference in soil carbon stocks between land use before the conversion and Afforestations CC11 is considered.

Afforestation > 20 years: Units of Land harvested since the beginning of the Commitment Period

In KP-CRF-Table A.1, changes in carbon stocks of Afforestations older than 20 years are reported. After 20 years, Afforestations are subject to normal Forest Management and the first thinnings and treatments are conducted. There is, however, no reclassification of these afforestated areas to Forest Management: all Afforesations after 1990 are reported under Article 3.3 (see Chapter 11.2.3). Emissions and removals for the carbon pools of Afforestations older than 20 years are calculated using the emission factors of productive (CC12) forests (see methodological description under “Forest Management”), since nearly all of the Afforestations (99.9%) develop to productive forests.

Deforestation

The differences in carbon stock of living biomass, litter and dead wood between forest land and the land-use type after the conversion is immediately accounted for after Deforestation (conversion time = 1 year). Losses in soil carbon due to disturbance caused by Deforestation and conversion to CC51 (buildings and constructions) are accounted for by reducing the difference in soil carbon stocks by 50% (Covington 1981; Rusch et al. 2009; see also Chapter 6.1.3.2) over a conversion period of 20 years (see Table 6-3; Chapter 6.8.2.2).

Forest Management

Living biomass

- Gain in living biomass (gross growth) of productive forests is used for “CC12 remaining” (Table 6-19). Gain of unproductive forests is used for “CC13 remaining” and amounts to zero (see Chapter 6.4.2.9; Table 6-4).
- Losses in living biomass reflects yearly cut and mortality in productive forests “CC12 remaining” (Table 6-19). Unproductive forests are not systematically harvested (description Chapter 6.4.2.9; Table 6-4). Thus losses of unproductive forests “CC13 remaining” are zero. Moreover, since yearly harvesting amounts from forest statistics (FOEN 2014h) are distributed over the productive forests, total harvesting in Swiss forests is accounted for under CC12 remaining.
- For the conversions between different forest source categories (“CC13 to CC12” and “CC12 to CC13”) the method is chosen in such a way that no potential carbon losses are underestimated: For areas which changed from “CC12 to CC13” the difference in carbon stocks of living biomass was considered and a net loss in carbon stock of living biomass is reported; in the case of a conversion from “CC13 to CC12” a gain-loss approach has been applied, since applying a stock-difference approach would lead to a considerable sink in living biomass in this category.

Litter, Dead wood and soil

- For productive forests "CC12 remaining", values for yearly changes in carbon stock of litter, dead wood and soil are used (Table 6-23). Estimates of those yearly changes were obtained from simulations with Yasso07 (see Chapter 6.4.2.8). For unproductive forests "CC13 remaining", yearly changes in litter and dead wood and soil carbon stock are assumed to be zero (Chapter 6.4.2.9).
- For the conversions between different forest categories ("CC13 to CC12" and "CC12 to CC13") the difference in carbon stock of dead wood, litter and soil carbon is taken into account (Table 6-23). For dead wood, the conversion "CC12 to CC13" leads to a net loss in carbon stock, in the case of a conversion "CC13 to CC12", a net gain is reported (Table 6-4).
- In the case of organic soils, emissions due to drainage are calculated as described in Chapter 6.4.2.11.

Differences in accounting for "Forest Sector 4A1 and 4A2" under the UNFCCC and „Forest Management" under KP Art. 3.4

Under KP Art. 3.4, natural forest regeneration is reported under "Forest Management" as CC12 or CC13 as soon as the KP definition of Forest is fulfilled and management activities have taken place. Changes within the activity "Forest Management" are reported under the Kyoto Protocol in the source categories "CC12 to CC13" and "CC13 to CC12".

Under the UNFCCC, all changes in land use from non-forest land to forest land are reported in the land-use category 4A2 for a conversion time of 20 years. For further details and a quantitative comparison see Chapter 11.3.2.2.

11.3.1.2 Justification when omitting any Carbon Pool or GHG Emissions/Removals from Activities under Article 3.3 and elected Activities under Article 3.4

KP LULUCF Table NIR1 (Table 11-1) summarizes the activity coverage and the carbon pools reported. When using the conservative Tier 1 approach (IPCC 2006 Volume 4, Chapter 1.3) assuming a specific carbon pool to be in balance, the carbon pool is indicated as not reported (NR). This is the case for litter and dead wood under Afforestation. Also for all pools of unproductive forests CC13, no changes are reported.

Change in Carbon Pool not Reported

11.3.1.2.1 Afforestation: litter and dead wood

Applying the stock-difference calculation approach, calculated changes in the litter and dead wood pool after an Afforestation are zero (see Chapter 6.4.2.10;Table 11-6). Since on Afforestations carbon stock in litter and dead wood is conservatively assumed to be zero (IPCC 2006, Chapter 4.3.2).

Figure 4.1 in Volume 1 Chapter 4.1.2 of IPCC (2006) illustrates the issue that, when data are not available, a "good practice method" should be used, that "financial resources for key categories should not be jeopardized" and an "appropriate tier level" should be used. Because Afforestation is not a key category (see Chapter 11.6.1), a conservative estimate (Tier 1) for the pools litter and dead wood is compliant to IPCC guidelines (IPCC 2006) for the first twenty years when no management activity takes place. Verifiable information to justify this approach is provided here:

- Changes in litter after Afforestation: Under the Kyoto Protocol, changes in the litter pool after Afforestations are not reported (conservative esimate). In an experiment by Zimmermann and Hiltbrunner (2012) litter accumulation of an Afforestation with Norway Spruce was determined 40 years after Afforestation. The authors found accumalation rates of 0.17-0.20 t C ha^{-1} yr^{-1}. Other studies show even higher accumlation rates of 0.24-0.34 t C ha^{-1} yr^{-1} for Afforestations with Norway spruce in Southern Alps (Thuille and Schulze 2006), 0.24 t C ha^{-1} yr^{-1} for Afforestation with ash and maple (Alberti et al. 2008) and 0.36 t C ha^{-1} yr^{-1} for Scotch pine (Vesterdal et al. 2002). Karhu et al. (2011) determined for Finisch forest stands mean annual rate of carbon accumulation in the litter over 18 years was 0.28 and 0.15 Mg ha^{-1} for Scots pine and birch, respectively.
- Based on a literature overview, Jandl et al. (2007) argued that the accumulation of a forest floor layer in, e.g., a conifer forest, is a C sink. The authors concluded that after Afforestation, forest floors accumulate C quickly. A long-term consequence of Afforestation is the gradual incorporation of C in the C pool of the mineral soil.Guidi et al. (2014) found that the C stocks in the organic layers were affected by LUC, with more C stored under early-stage forest compared with grassland abandoned 10 years ago, and highest C stocks were found under the old forest dominated by Fagus sylvatica and Picea abies.
- Changes in dead wood after Afforestation: changes in the dead wood pool after Afforestations are conservatively not reported. Zimmermann and Hiltbrunner (2012) showed that 40 years after Afforestation with Norway Spruce, dead wood volume amounted to 10.4 t C ha^{-1}. Thus, an annual increase in dead wood of 0.26 t C ha^{-1} yr^{-1} for Afforestations with Norway Spruce can be derived from this case study, considering the fact that on grassland, the starting point of most Afforestations, there is no dead wood available.
- Besides the results of the case studies listed above, a reasoning based on sound knowledge of likely system responses (Grassi and Blujdea 2011) is provided: At stand level, the pools dead wood and litter of Afforestation on cropland and grassland cannot be a source, especially if previous land use did not have perennial woody biomass. On Afforestations, tree growth follows an exponential pattern, which can also be assumed for the accumulation of litter and dead wood.

Note that for Afforestations older than 20 years, estimates of carbon stock changes in dead wood, litter and soil are reported.

11.3.1.2.2 Unproductive Forests CC13

A description of unproductive forests and the reasoning why these pools are in equilibrium and thus not a source is given in detail in Chapter 6.4.2.9.

Based on the fact that unproductive forest land only covers 7-8% of the area under Forest Management (Table 6-8 and CRF-KP-Table 4(KP.I)B) and based on the description of these stands given before, emissions or removals of any of the pools of unproductive forests cannot account for more than 25% of the activity Forest Management. According to Fig 1.2 in IPCC 2006 Volume 4 note 4, 25% is the threshold that would require a higher Tier. Since Swiss resources are limited and it was not not wanted to jeopardize financial resources for the key categories (IPCC 2006 Volume 1 Chapter 4.1.2 Fig. 4.1), Switzerland decided to use the Tier 1 approach and reports no changes in living biomass, litter, dead wood and soil of unproductive areas arguing that this is a conservative estimate. Emissions from organic soils are accounted for using default factors from IPCC 2014 (Tier 1).

Greenhouse Gas Sources Reported

- Fertilization of forests is prohibited by the Swiss forest law and adherent ordinances (Swiss Confederation 1991, 1992). Additionally, the “Ordinance on Chemical Risk Reduction“ (Swiss Confederation 2005) prohibits the application of fertilizers, including liming, in forests. Thus, emissions from fertilization are reported as “not occurring”.
- Drainage of forests is not a permitted practice in Switzerland and since 1991 not a permitted practice in Switzerland (Swiss Confederation 1991). All organic forest soils are conservatively reported as drained, which is definitely an overestimation. CO_2 emissions due to drainage are calculated as described in Chapter 6.4.2.11. N_2O emissions from drainage of organic soils was calculated as described in Chapter 6.4.2.12.
- Biomass burning: emissions of CO_2, CH_4 and N_2O are reported. The calculation of these emissions is described in Chapter 6.4.2.13.

11.3.1.3 Information on whether or not indirect and natural GHG Emissions and Removals have been factored out

No anthropogenic GHG emissions and removals from elevated carbon dioxide concentrations, indirect nitrogen deposition or the dynamic effects of the age structure resulting from LULUCF activities under Article 3, paragraphs 3 and 4 prior to 01 January 1990 have been factored out.

The IPCC does not give specific methods for factoring out these effects. Besides this, there are no reliable country-specific data available. Investigations on elevated CO_2 concentrations on growth showed complex relationships in the mid-term. Some species showed an increase others a decrease and some no change in growth (Bader el al. 2013). Opposing patterns are also reported regarding the effect of nitrogen deposition: A postive effect of N deposition on growth was found by e.g., Spiecker 1999; and Jarvis and Linder 2000. Other studies (e.g., Hyvönen et al. 2008; Högberg et al. 2006; Braun et al. 2010; Gschwantner 2006; Meining et al. 2008) indicate that N-deposition, while leading to soil acidification, can casue a reduction in growth. Such acidification processes are widely detected in Swiss forest soils.

11.3.1.4 Changes in Data and Methods since the previous Submission (Recalculations)

This is the first submission in the second commitment period using the methodology from 2/CMP.7 and the KP-Supplement (IPCC 2014). Table 10-1 (recommendations) and Table

10-2 (encouragements) list the improvements made since last year based on the questions, recommendations and ecouragements of the UNFCCC Expert Review Team.

Methodological improvements for the forest sector valid for the LULUCF and KP-LULUCF sector are listed in Chapter 6.5.5. The following Kyoto-specific methodological modifications were made for this submission:

- The calculation of carbon stock changes in living biomass after Afforestation has been adapted such that it is harmonized between reporting under the UNFCCC and accounting under the KP: the age-specific emissions factors were replaced by average emission factors (see Chapter 11.3.1.1).
- Net CO_2 emissions and removals from harvested wood products (HWP) are reported for the first time using the methodology from the KP-Supplement (IPCC 2014).
- N_2O emissions from mineralisation of organic matter in mineral forest soils due to land-use changes are reported for the first time.

11.3.1.5 Uncertainty Estimates

An overview of the uncertainty estimates of activity data is discussed in detail in Chapter 6.1.5 and is shown in Table 6-10. Uncertainty estimates of emission factors for the reported activities under the Kyoto Protocol are shown in Table 6-5, overall uncertainties in Table Table 11-7.

A detailed description of the determination of the emission factor uncertainty of Forest Management can be found in Chapter 6.4.3. Table 6-5 lists the relative uncertainties in the LULUCF sector: an uncertainty of 45% was calculated for Afforestations, 50% for Deforestations and 45% for Forest Management.

Lands fulfilling the definition of Forest (see Chapter 11.1.1) are accounted for under "Forest Management". This means, that the area under Forest Management which is the result of natural regeneration is attributed the uncertainty of Forest Management.

Table 11-7 Uncertainty estimates of activity data and emission factors and the overall uncertainty of activities reported under the Kyoto Protocol Article 3.3 and Article 3.4

Activity under KP	Associated category in UNFCCC inventory (chapter 7.3)	Activity data uncertainty	Emission factor	Combined uncertainty
Afforestation	5A2 Land converted to Forest Land	2	45	45
Deforestation	mainly 5E2 Land converted to Settlements	5	50	50
Forest Management	5A1 Forest Land remaining Forest Land	2	45	45

11.3.1.6 Other methodological Issues

The methodology used for reporting under the Kyoto Protocol is described in detail in previous sections.

N_2O emissions as a result of the disturbance associated with land-use conversion (Deforestation) to Cropland are reported in KP-CRF-table 4(KP-II)3. The emissions are calculated according to the methodology described in Chapter 6.10.

11.3.1.7 The Year of the onset of an Activity, if after 2008

The starting year of the activities reported can directly be derived from the land-use change matrix (Table 6-9), from wich a continuous time series is derived (Table 11-5).

11.3.2 Category-Specific QA/QC and Verification

In Chapter 6.4.4 category-specific QA/QC and verification items for forest land are described in detail. The general QA/QC measures are described in section 1.2.3.

11.3.2.1 Changes in Soil Carbon Stock under Afforestation CC11

The fact that soils are acting as small sinks under Afforestation is supported by Jandl et al. (2007) who reviewed several studies on the effect of different forest management systems (including Afforestations) on soil carbon sequestration and concluded that a long-term consequence of Afforestation is the gradual incorporation of carbon in the mineral associated soil carbon pool.

11.3.2.2 Comparison of the Forest Areas reported in the CRF-tables and KP-CRF-tables

A direct comparison of the areas reported in the CRF-tables under the Convention "Forest Land remaining Forest Land" (CRF-Table 4A) and under "Forest Management" under the Kyoto Protocol (KP-CRF-Table 4(KP-I)B.1) is not possible due to the different structure of these CRF-tables and due to different reporting requirements:

- Conversions to Forest Land which are not human-induced (natural regneration) are not accounted for as “Afforestations under the Kyoto Protocol”. These areas are reported under KP Art. 3.4 Forest Management in KP-CRF-table 4(KP-I)B.1 as soon as the definition of Forest is fulfilled. Under the Convention, these Afforestations are reported under land-use category 4A2 with a conversion time of 20 years.
- Afforestations under the Kyoto Protocol which are older than 20 years are always reported under Art. 3.3 (subdivision > 20 years in KP-CRF-table 4(KP-I)A.1: units of land harvested since the beginning of the commitment period). Thus, there is no reclassification of the units of lands reported under Art. 3.3. In contrast, under the UNFCCC, the Afforestations older than 20 years are relocated to the land-use category 4A1 “Forest Land remaining forest land”.
- Not all changes from a forest combination category (CC11, CC12, CC13) to a non-forest combination category correspond to the definition of Deforestation according to the Kyoto Protocol Art. 3.3. (see above). These areas remain under the KP Art. 3.4 activity Forest Management and are included in the areas as reported in KP-CRF-table 4(KP-I)B.1.
- Reporting of land-use changes LUC: Since only the KP activity “Forest Management” is accounted for under KP Art. 3.4, changes from other KP activities to forest land are not reported as land-use change, but are reported as CC12 or CC13 as soon as the KP definition of forest is fulfilled. Only conversions within the activity “Forest Management” are reported under the KP, i.e. CC12 to CC13 and CC13 to CC12. Under the UNFCCC, land-use change to forest land are reported in category 4A2.

In a study by Meteotest (2013a) the reported activity data for the inventory year 2012 have been checked and compared (Table 11-8). It could be shown that the differences in the CRF-tables can be explained and that the resulting budget of areas reported under the Convention and the Kyoto Protocol are identical. The cross-check was not updated for the present submission because CRF-tables were not available by the editorial deadline.

Table 11-8 Area budget (in kha) of KP-LULUCF and LULUCF under the UNFCCC in the year 2012 for forest land and Afforestations. The references in the table are valid for the CRF-Tables used until 2012.

activity	**Table, Cells**	**area UNFCCC** kha	**area KP** kha	**Check Difference** kha	**remarks**
All Forest Land					
Forest Management	5(KP-I)B.1, C9		1'232.660		a)
Afforestations <= 20 years	5(KP-I)A.1.1, C10		1.697		b)
Afforestations > 20 years	5(KP-I)A.1.2, C10		0.793		c)
Total area KP			1'235.150		
Non-Kyoto loss of forest cover			-0.670		d)
Forest Land UNFCCC	5.A, C10	1'234.480			e)
Total		1'234.480	1'234.480	0.000	
Afforestation, CC11					
UNFCCC	5.A, C31+C35+C39 +C43+C47	1.697			f)
KP	5(KP-I)A.1.1, C10		1.697	0.000	g)

Remarks:

a) KP Forest Management consists of CC12 and CC13 areas fulfilling the criteria of the KP.

b) KP Afforestations are afforested areas since 1990 cumulated over 20 years at most.

c) KP Afforestations "older than 20 years" (>20 years) is the area that has been afforested since more than 20 years. In the UNFCCC tables these areas belong to 4A1 (CC12 or CC13).

d) The non-Kyoto loss of forest cover is the part of the total area of forest loss (reported under UNFCCC) not fulfilling the definition of deforestations according to the Kyoto Protocol (see NIR Chapter 11.2.3). For the comparison this area must be subtracted from the KP forest area.

e) The total Forest Land in CRF 4A covers productive forests (CC12), unproductive forests (CC13) and afforestations (CC11). It is congruent with the forest area derived from the aerial photos of the AREA survey (NIR Chapter 6.2.2).

f) The CC11 area in UNFCCC can be taken from CRF 4A2 by summing up the afforestation source categories.

g) The cumulated (20 years) CC11 area of KP and UNFCCC are congruent.

11.3.2.3 Impact of Forest Management on Changes in Carbon Stocks in Soil and in Litter

Accounting for forest management impacts on carbon storage in litter and soil in Swiss productive forests with Yasso07

To estimate carbon stocks and carbon stock changes in the reported litter and soil pools, Switzerland uses the carbon cycling model Yasso07 (cf. Didion et al. 2012, 2014). Yasso07 requires information on carbon inputs from dead organic matter (i.e. non-woody inputs, including foliage and fine roots, woody inputs, including standing and lying dead wood and dead roots) and climate (temperature, temperature amplitude and precipitation)". The carbon inputs are obtained for each plot in the National Forest Inventory (NFI) that is simulated with Yasso07. The NFI plots have been repeatedly measured since the first inventory in 1985 and, hence, observed changes in the volume of living and dead biomass reflect, among other, the site-specific impact of forest management. Based on harvesting statistics and allometric relationships, the production of dead wood (incl. dead roots, stems, stumps and branches) and litter from living trees (i.e. controlled by forest management) and as harvest residues are estimated.

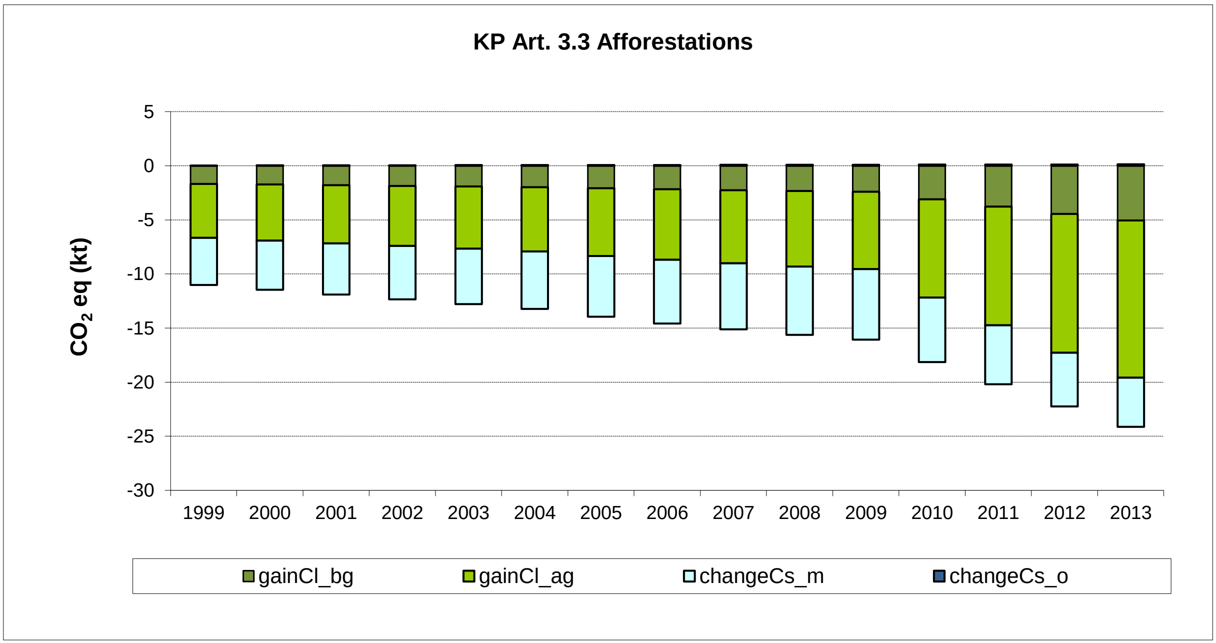
Thus, the Yasso07-model reflects the impact of forest management: forest management effects on carbon stocks in litter (including non-woody and woody material) and soil are fully accounted for in the Swiss GHG inventory (Didion 2014).

Literature Review

A detailed screening of the available scientific literature on the impact of forest management on carbon stock changes in litter and soils is provided in Didion (2014). The majority of studies indicated no significant effect of forest management on soil carbon stocks with the exception of clearcutting (e.g. Jandl et al. 2007). Since silvicultural practices in Switzerland are regulated by law and exclude intensive management options such as clearcuts, fertilization or liming (Swiss Confederation 1991, 1992), no or only minor forest management impacts on soil carbon stocks can be expected. The production of litter is directly affected by silvicultural practices since the removal of trees results in harvest residues and in a decrease in the amount of remaining foliage (e.g. Van Miegroet and Olsson 2011). Generally, the impact of forest management on litter production is temporary and losses of litter carbon can be rapidly replaced (Nave et al. 2010).

11.4 Article 3.3.

Figure 11-2 shows removals of CO_2 eq from Afforestations and emissions of CO_2 eq from Deforestations for the years 1999-2013. The corresponding values are listed in Table 11-4.



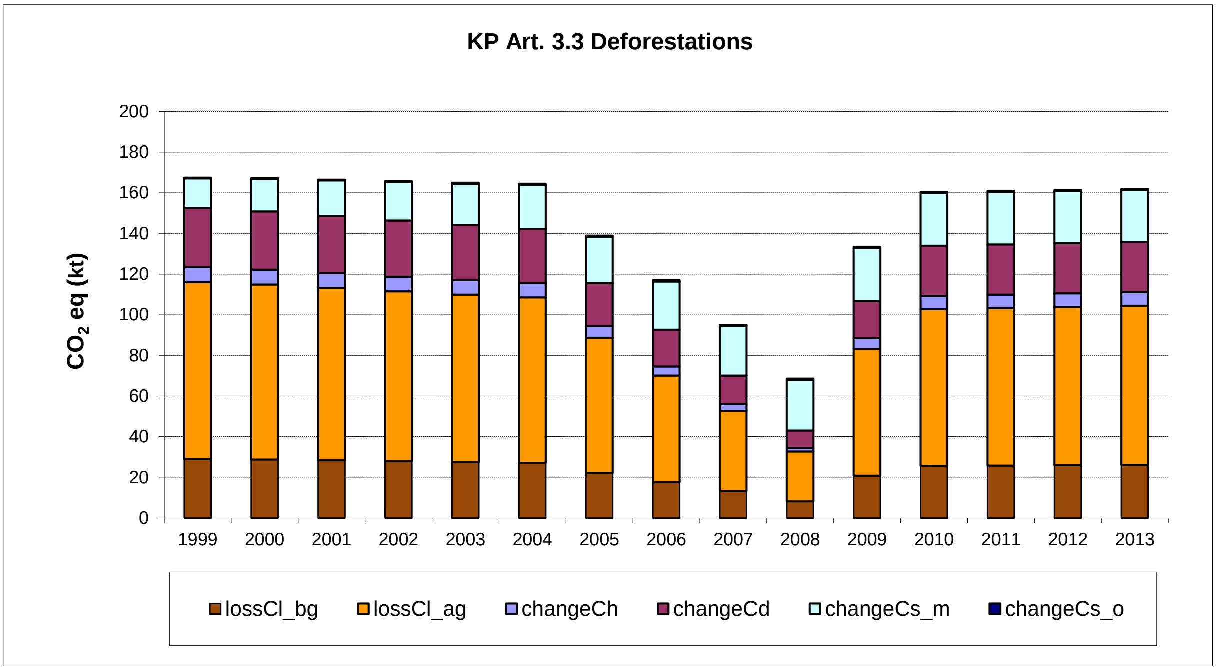


Figure 11-2 Removals (negative sign) and emissions (positive sign) of CO_2 eq from Afforestations (upper panel) and from Deforestations (lower panel) shown per carbon pool, 1999-2013. Belowground and aboveground living biomass are reported separately. Used abreveations explained in Chapter 6.1.3.2; C_{l_ag}: C above-ground living biomass; C_{l_bg}: C below-ground living biomass; C_h: C in litter, C_d: C in dead wood, C_{s_m}: C in mineral soil; C_{s_o}: C in organic soil.

Removals from Afforestations and emissions from Deforestations differ by one order of magnitude (Figure 11-2, Figure 11-3). Since carbon from living biomass is immediately removed after clear-cutting, Deforestation can be seen as a process where carbon is lost over a very short time. In contrast, Afforestation is a “slow process where carbon is sequestered and accumulated over decades. CO_2 emissions on organic soils under Afforestations and Deforestations are due to former drainage (see Chapter 11.3.1.2).

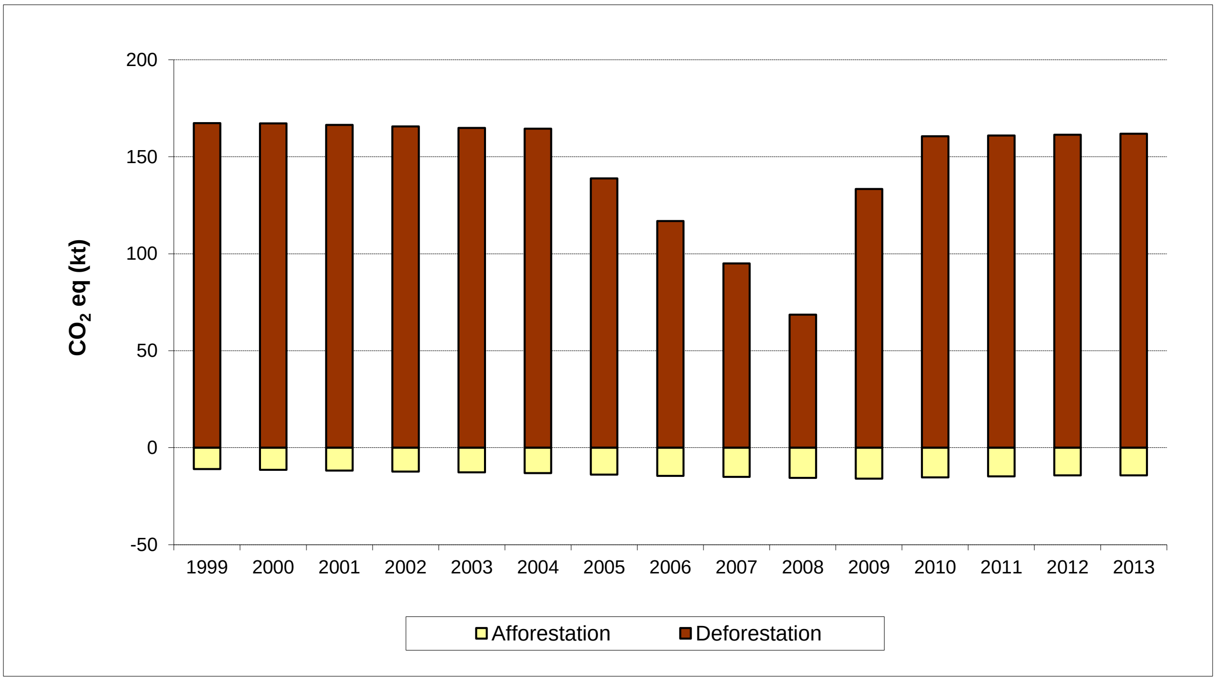


Figure 11-3 Removals (negative sign) and emissions (positive sign) of CO_2 eq of Afforestations and Deforestations, 1999-2013.

11.4.1 Information that demonstrates that Activities under Article 3.3. began on or after 1 January 1990 and before December 2020 and are direct Human-induced.

The Swiss definitions of Afforestation and Deforestation only consider directly human-induced activities (see FOEN 2006h, Sect. E and FOEN 2010d).

Reforestation

For more than 100 years, the area of forest in Switzerland has been increasing (see Chapter 11.5.3). A decrease in forest area as a result of Deforestation is not possible, since deforestation is strongly regulated by the Federal Law on Forests (Swiss Confederation 1991). Therefore, reforestation of areas not forested for a period of at least 50 years does not occur in Switzerland (FOEN 2006h, Sect. E). Switzerland only considers Afforestation and Deforestation under Article 3, paragraph 3.

Afforestation

Switzerland is very restrictive in reporting Afforestations under the Kyoto Protocol and only reports planted Afforestations (see Chapter 11.1.3; FOEN 2010h).

The annual rate of Afforestation since 1990 is assessed based on AREA data (Chapter 6.3). For reporting under the Kyoto Protocol, afforested areas since 1990 always remain in the “Afforestation” category. Therefore, the area of Afforestations is increasing since 1990 (see Table 11-5).

Afforestations older than 20 years are subject to normal Forest Management practices including harvesting (see Chapter 11.3.1.1). These areas are reported in CRF-tables 4(KP-I)A.1.

Deforestation

In Switzerland, direct human-induced Deforestation is subject to authorization (Swiss Confederation 1991, Art. 5). Deforestation is only allowed for projects with public interests and in these cases, the deforestation has to be compensated by an afforestation of equal area.

For details concerning the classification of Deforestations under the Kyoto Protocol see Chapter 11.2.3). Only Deforestations carried out after 01 January 1990 are considered. For reporting under the Kyoto Protocol, deforested areas since 1990 remain in the Deforestation category. Therefore, the area of Deforestations is increasing since 1990 (see Table 11-5). Since Switzerland only accounts for KP Art. 3.4 activity “Forest Management”, these deforested areas are not subject to another KP Art. 3.4 activity.

11.4.2 Information on how Harvesting or Forest Disturbance that is followed by the Re-Establishment of Forest is distinguished from Deforestation

The Swiss definition of Deforestation only covers permanent conversions from forest land into non-forest land and is assessed by AREA applying the criteria discussed in chapter 11.2.3. This approach is confirmed by Sigmaplan (2012a).

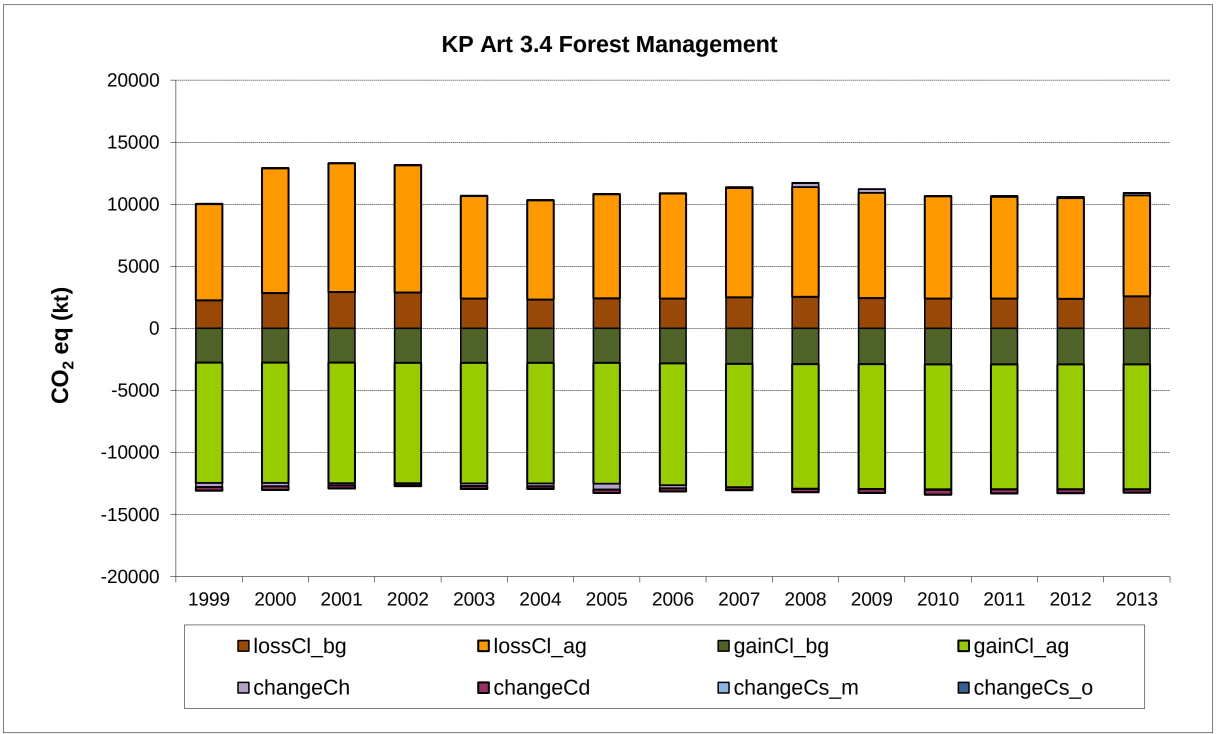
They implicitly distinguish between permanent conversions and transient situations like harvesting or forest disturbance. Construction of e.g. pipelines and power supply lines within a forest area are transient situations (see Chapter 11.1.3 and 11.2.3; Brändli 2010). As described in FOEN (2010d), these non-permanent conversions are not classified as Deforestation under the Kyoto Protocol.

11.4.3 Information on the Size and Geographical Location of Forest Areas that have lost Forest Cover but which are not yet classified as Deforested

The AREA survey provides a detailed overview of land-use changes with regard to land cover and land use (see Chapter 6.2 and 6.3). Temporal changes of land cover can lead to a reclassification in AREA from a forest category to a non-forest category. In FOEN (2010d) and in Chapter 11.2.3 the criteria are listed which conversions from a forest combination category to a non-forest combination category are not identified as Kyoto Deforestation under the Kyoto Protocol.

11.5 Article 3.4

CO_2 eq emissions and removals from the reported pools and total CO_2 eq emissions and removals of the Kyoto Protocol activity Forest Management for the years 1999 until 2013 are shown in Figure 11-4. The corresponding values are listed in Table 11-4.



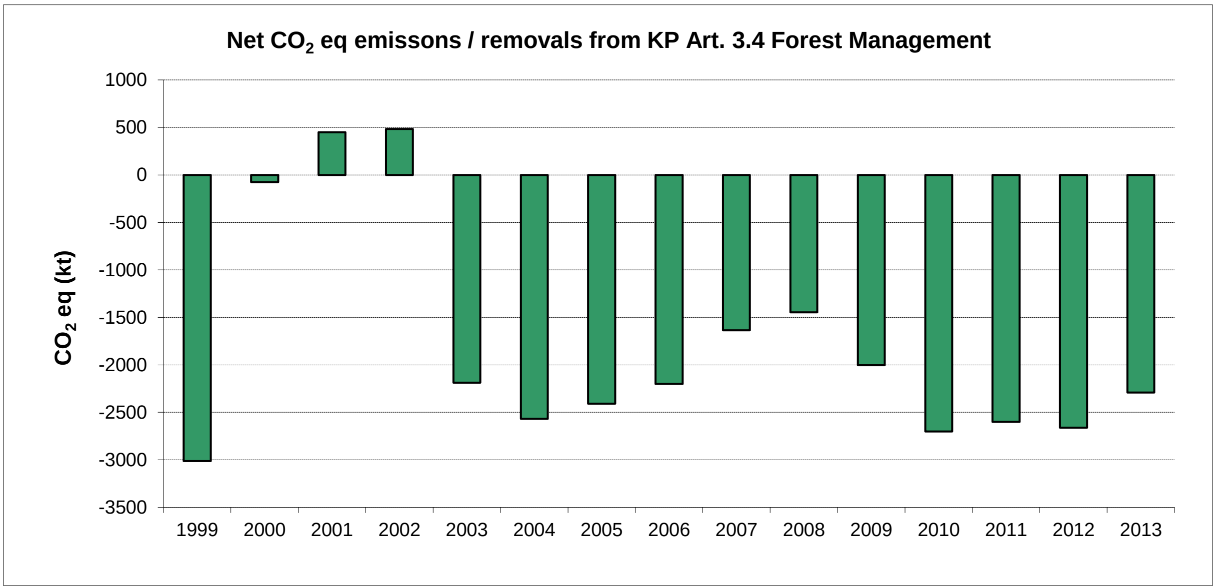


Figure 11-4 CO_2 eq emissions (positive sign) and removals (negative sign) from the reported carbon pools under Forest Management (upper panel) and the total CO_2 eq emissions and removals from Forest Management (lower panel), 1999-2013. Belowground and aboveground living biomass are reported separately. Used abreveations explained in Chapter 6.1.3.2; C_{l_ag}: C above-ground living biomass; C_{l_bg}: C below-ground living biomass; C_h: C in litter, C_d: C in dead wood, C_{s_m}: C in mineral soil; C_{s_o}: C in organic soil.

The yearly fluctuations in the GHG emissions and removals from Forest Management can mainly be explained by changes in the losses of living biomass, dead wood and litter (see Table 11-4). Changes in the area of managed forest are relatively small (Table 11-5). In 2001 and 2002 Forest Management was a small source of CO_2 eq. and in 2000 a small sink compared to the remaing years. This was due to an elevated amount of losses in living biomass after storm Lothar, which caused large-scale damaged in Swiss forests in December 1999.

11.5.1 Information that demonstrates that Activities under Article 3.4. have occurred since 1 January 1990 and are Human-induced

According to the Swiss Federal Law on Forests, the extent and the spatial distribution of the total forest area in Switzerland has to be preserved (Swiss Confederation 1991, Art. 1) and thus, any change of the forested area has to be authorized. All Swiss forests are under continuous observation of the Swiss Forest Service and monitored by the NFI. Therefore, all forests in Switzerland are subject to Forest Management (FOEN 2006h, Sect. F).

11.5.2 Information relating to Cropland Management, Grazing Land Management and Revegetation, if elected, for the Base Year

Not applicable.

11.5.3 Information Relating to Forest Management

There is a long tradition of forest protection in Switzerland. The first federal Forest Act came into force in 1876, but it only covered the higher-elevation region. Its aim was to put a halt to the depletion of forests, to manage the remaining forest areas in a sustainable way, and to promote Afforestation. The Forest Act of 1902 covered the whole country. The Forest Act as well as an enabling overall economic development resulted in an increase of the forested area in Switzerland by nearly 50% today compared to the mid-19th century (Figure 11-5). Also growing stock increased significantly due to changes in Forest Management practices. The Forest Act (Swiss Confederation 1991) that came into force in 1993 reaffirms the long-standing Swiss tradition of preserving both forest area and forest as a natural ecosystem. It prescribes sustainable Forest Management, prohibits clearing, and bans Deforestation unless it is replaced by an equal area of afforested land or an equivalent measure to improve biodiversity.

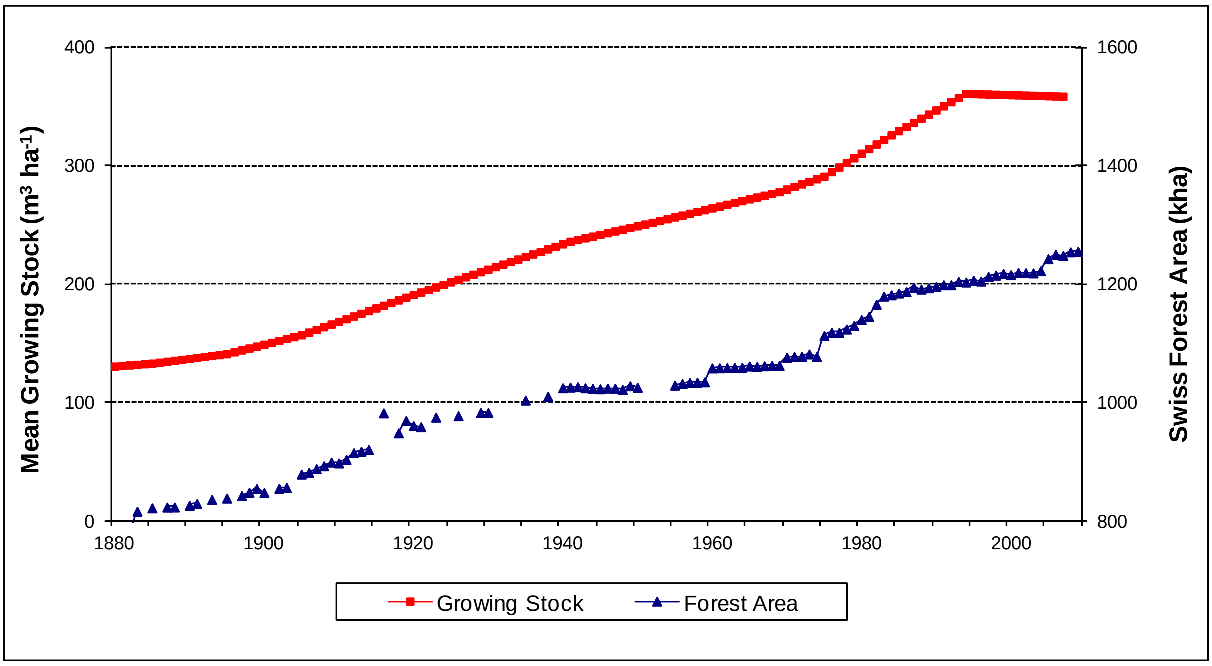


Figure 11-5 Historical mean growing stock and forest area in Switzerland since 1880.

In 2004, the Swiss national forest programme was published, outlining an action plan for the period 2004-2015 (SAEFL 2004b). It specifies five priority objectives: (1) the forest's protective function is guaranteed, (2) the economic viability of the forestry sector is improved, (3) the value-added chain for wood is strengthened, (4) biodiversity is conserved and (5) forest soils, trees and drinking water are not threatened. These objectives encompass that CO_2 removals by sinks and emissions by sources in the forests shall be recognized in terms of compliance with the Kyoto Protocol while making better use of the potential of forests for timber production and fuel wood through economic incentives and implementing new technologies.

In November 2006, the Swiss government communicated in its initial report to the UNFCCC that Switzerland will be accounting for Forest Management under Article 3.4 of the Kyoto Protocol (FOEN 2006h).

To implement the objectives of the national forest programme (SAEFL 2004b), FOEN has formulated its wood resource policy (FOEN 2008h) which is coordinated with the other relevant sectoral policies (e.g. energy policy, regional development policy). This wood resource policy defines, among other things, the direction to be taken by federal policy in relation to wood promotion on completion of the "Wood 21" wood promotion programme which was terminated at the end of 2008. Under this programme, a wood action plan was started in 2009. The main focus in the implementation of the action plan lies on the ecologically and economically effective use of wood. Regarding the efficient use of wood, cascade use is prioritized, i.e. wood is used as material prior to its use for energy. In the case of energy use, greater overall efficiency of the conversion technology should be targeted.

11.5.4 Information that demonstrates that Emissions and Removals resulting from elected Article 3, Paragraph 4, Activities are not accounted for under Activities under Article 3, Paragraph 3

This information is requested in the Annex to 15/CMP.1 paragraph 9.c. The reporting of Forest Management under article 3, paragraph 4 is clearly separated from the reporting of the activities under article 3, paragraph 3.

Units of lands with ARD (Afforestation, Reforestation and Deforestation) activities, are reported under Article 3, paragraph 3. These areas always remain under Article 3, paragraph 3. Afforestations older than 20 years are attributed to emissions factors of mature forests under forest management. These units of lands are reported in Table 4(KP-I)A.1 and not under forest management. Thus, there is no double counting of units of lands under article 3, paragraph 3 to Article 3, paragraph 4. Table 11-8 shows the clear distinction between units of land subject to activities under Article 3, paragraph 3 and Land subject to Forest Management under Article 3, paragraph 4.

11.5.5 Information that indicates to what extend Removals from Forest Management offsets the Debit incurred under Article 3, Paragraph 3

This information is shown in the summary KP-CRF-Table "Information table on accounting for activities under Articles 3.3 and 3.4 of the Kyoto Protocol.

11.6 Other Information

11.6.1 Key Category Analysis for Article 3.3. and 3.4. Activities

The results of the approach 1 key category analysis including LULUCF are shown and explained in Chapter 1.5 and are displayed in Table 1-4, and Table 1-10 for the year 2013. The smallest UNFCCC category, and therefore also the smallest LULUCF category, considered key based on an approach 1 assessment is “5D Wastewater treatment and discharge, CO_2” with a contribution of 173.34 kt CO_2 eq.

The following LULUCF activities under the Kyoto Protocol are listed in Kyoto Table NIR 3 (Table 11-3) because their associated LULUCF categories in the UNFCCC inventory are key categories under the level or trend assessment:

- Forest Management (-2 290.79 kt CO2 eq, encompasses all greenhouse gass emissions; Table 11-4) is a key category under the Kyoto Protocol because its absolute contribution is higher than the smallest category considered key in the UNFCCC inventory. This activity is associated with the UNFCCC category „Forest Land remaining Forest Land“ (-2'258.41 kt CO2 eq, encompasses only CO_2 emissions). Since the total Swiss forest is considered as managed, there is a good agreement between the category under the Kyoto Protocol and the UNFCCC inventory category. According to Table 1-10 the UNFCCC category ”Forest Land remaining Forest Land“ is only level key category under an approach 2 assessment in 2013.
- Afforestation and Reforestation (-14.32 kt CO2 eq; Table 11-4) is not a key category under the Kyoto Protocol because its absolute contribution is substantially lower than the smallest category considered key in the UNFCCC inventory. The contribution of the

associated UNFCCC category “Land converted to Forest Land” is -425.44 kt CO2 eq. It includes converted areas after natural regenerations due to abandonment of land, which are not reported as Afforestation under the Kyoto Protocol. The UNFCCC category “Land converted to Forest Land” is both level and trend key category under an approach 2 assessment in 2013 (Table 1-10).

- Deforestation (161.92 kt CO2 eq; Table 11-4) is a key category under the Kyoto Protocol because its contribution is higher than the smallest UNFCCC category considered key. The associated UNFCCC category is „Land converted to Settlements” (307.51 kt CO2 eq), but only a part of this UNFCCC category represents the activity Deforestation under the Kyoto Protocol (see Chapter 11.2.3). The UNFCCC category ”Land converted to Settlements” is both level and trend key category under an approach 2 assessment in 2013 (Table 1-10).
- Harvested Wood Products (-158.15 kt CO2 eq; Table E- 7) is not a key category under the Kyoto Protocol because its contribution is lower than the smallest UNFCCC category considered key. Exactly the same method is used for calculation of HWP under UNFCCC and KP. The UNFCCC category ”Harvested Wood Products” is trend key category under an approach 2 assessment in 2013 (Table 1-10).

11.7 Technical Correction Forest Management Reference Level

Switzerland’s forest management reference level (FMRL) is documented in FOEN (2011l). The Swiss FMRL is inscribed in the appendix to the annex to Decision 2/CMP.7 and amounts to +0.220 Mt CO_2 eq. yr^{-1}. FOEN (2011l) was subject to a technical assessment. Based on the technical assessment report (UNFCCC 2011a) and applying guidance of IPCC (2014), the following technical corrections of Switzerland’s FMRL have been made:

- Modelling changes in carbon stocks of living biomass: To model changes in living biomass, a revised version of the model Massimo 3 is used.
- The implementation of the business-as-usual harvesting scenario (BAU) into the model Massimo has been corrected.
- Modelling changes in carbon stocks of litter, dead wood and soil carbon: The model Yasso07 has been implemented in Switzerland since FOEN 2013.
- Calculation of carbon stock changes in HWP: carbon stock changes in HWP are calculated following the IPCC methodology (IPCC 2014); the historical time series has been updated (see Chapter 6.11).
- Emissions from forest fires and from organic soils have been incorporated into the FMRL (paragraph 16 of UNFCCC 2011a).
- The area under Forest Management for 2013–2020 has been calculated using a linear extrapolation (paragraph 15 of UNFCCC 2011a), based on updated activity data for 1990–2009 (as used for FOEN 2014).

11.7.1 Modelling changes in Carbon Stocks of living Biomass

To model changes in living biomass, the model Massimo is used (Fischer et al. 2015, Kaufmann 2011, Kaufmann 2001, Kaufmann 2001a). A detailed description of the model implementation for the FMRL can be found in Didion et al. (2014b). Besides general improvements, also FMRL-specific modifications have been made since January 2011:

- General improvements: improved usability, implementation of more accurate harvest interventions and more realistic tree regeneration.
- The time step of 10 years in the base version of the model was shortened to 5 years. This represents a reasonable approach to obtain a finer temporal resolution required for constructing, and future accounting based on the FMRL, which does not compromise the accuracy of the model. Since Massimo is based on NFI data which were collected at 10-year intervals until the NFI3 in 2006. Further refinements concerning the model time step would result in a loss of accuracy because different processes become dominant at shorter intervals that are not reflected in the decadal data.
- Validation of the model: The model was initialized with NFI 3 data. For the validation, it was driven by observed harvest rates in NFI 4b (Abegg et al. 2014). As NFI 4b data were not used for model calibration, this is an independent model validation. The validation showed that the model Massimo is assessed as a valuable tool to simulate short-term development of Swiss forests based on predefined management scenarios.

11.7.2 Correction of Implementation of the business-as-usual harvesting Scenario (BAU)

11.7.2.1 Description of the BAU harvesting Scenario

The determination of BAU in FOEN (2011l) is based on:

- The extrapolation of historical data;
- Switzerland's Wood Policy elaborated in two scientific studies
  - Switzerland's Potential Sustainable Wood Supply (FOEN 2008h)
  - Wood Market Model (Pauli et al 2009)

A screening of these policies and studies resulted in the determination of Switzerland's BAU harvesting scenario with an increase of harvest of on average 30% over the period 2013-2020 compared to 1990-2007 (FOEN 2011l).

A succinct and corrected description of the determination of Switzerland's BAU harvesting scenario is given in this section. Policy assumptions and the available studies to determine Switzerland's BAU-harvesting scenario have not changed. However, some of the numbers in the referred studies and in the description of FOEN (2011l) have been rectified.

The target values and years, either calculated from extrapolation of historical data or defined in the policy documents or scientific reports, are summarized in Table 11-9.

- Extrapolation of historical data: no corrections have been made compared to FOEN (2011l). The starting year is 2008, since historical data until 2007 are used. Historical data are taken from the Swiss Forest Statistics (FOEN 2009) and upscaled for underestemation by using a mean factor of 17% (Altwegg et al. 2010).
- Potential Sustainable Wood Supply: Switzerland's Wood Policy defines that the level of the "Potential Sustainable Wood Supply" (PSWS) should be exploited until 2020 (FOEN 2008h). The value for this PSWS has been recalculated in Hofer et al. (2011) using data from the National Forest Inventories (NFI; see Chapter 6.4.2.1) for the periods 1986-

1994 (NFI12) and 1995-2006 (NFI23). This corrected value, based on NFI data before 2010 and based on the same assumptions as in the prevous study (Hofer and Altwegg, 2008), has also been adopted in the Swiss Forest Policy 2020 (2013) and in the official description of Switzerland's Wood Policy (FOEN/SFOE/EAER 2014). The recalculated value for the Swiss Potential Sustainable Wood Supply, equaling the harvesting amount to be exhausted in 2020, amounts to 8.23 Mio m^3. For the period 2013-2020 compared to 1990-2007, this corresponds with an increase of 40% assuming a linear pathway or 31% assuming an exponential pathway (see below for further explanation).

- Switzerland's Wood Policy: the results in the studies Hofer and Altweg (2008) and Pauli et al. 2009 are based on modeling work with MASSIMO. This model has been updated (see Chapter 11.7.1) leading to correction of the values. Using a modeling interval in this studies of 10 years, the starting year is 2006 (in FOEN 2011l it was 2005) and the harvesting value for 2006 is fixed at 6.7 Mio m^3. This starting value is derived from cut and mortality at NFI23 by using an average mortality rate of 14% (average of NFI12, NFI34b; see also Didion et al. 2014). From this point, the same scenarios (scenario basic, scenario increase energy cost, scenario constant carbon stocks) as in FOEN 2011l are modeled with Massimo (Table 11-9), but different results are obtained due to the update of the model.

Table 11-9: Target values of harvesting rates based on different methods or studies: linear extrapolation of data from the Swiss Forest Statistics (trend 1990-2007 and trend 2003-2007), Potential Sustainable Wood Supply (PSWS) that should be exhausted in 2020 (linear and exponential pathway) and the scenarios defined by Pauli et al. (2009; increase in energy costs, basic and constant carbon stocks). The relative increase in harvesting rates is calculated by comparing the mean value of 2013-2020 with the mean value of 1990-2007 (5.62 Mio m^3).

	Extrapol. Trend 1990-2007	Extrapol. Trend 2003-2007	PSWS exhausted 2020 (lin)	PSWS exhausted 2020 (exp)	Scenario constant C stocks	Scenario basic Scenario	Scenario increase energy cost
Target value 2020 Mio m^3	7.64	9.29	8.23	8.23	7.51	8.11	8.45
Mean 2013-2020 Mio m^3	7.32	8.60	7.85	7.35	7.31	7.76	8.01
% Increase (mean 2013-2020 / mean 1990-2007)	30%	53%	40%	31%	30%	38%	42%

Table 11-9 shows, that, considering the corrected values from the updated studies, the harvesting amount to be reached in 2020 is higher for certain methods than in FOEN (2011l).

- In FOEN 2011l, BAU harvesting amount was similar (ca. 30%) for the extrapolation of the trend 1990-2007, for the basic scenario from Pauli et al. (2009) and for the potential sustainable wood supply PSWS, to be exploited in 2020 according to the Swiss wood policy.
- After correcting the data, the harvesting rate ranges between roughly 30% (extrapolation trend 1990-2007; exhaustion of the PSWS with an exponential pathway), 38% for the basic scenario from Pauli et al.(2009) and even 40% for the exhaustion of the PSWS with a linear pathway.

In FOEN (2011l), the pathway of reaching the target value is not defined. For calculation of Switzerland's FMRL, we used an exponential pathway, reflecting the fact that policies, adopted and implemented no later than December 2009, only have a moderate impact at the beginning of the second commitment period and take effect at the end of the commitment period. Applying this exponential pathway has the following advantages:

- Using a BAU-scenario with an exponential pathway results in a conservative way of accounting for FM with FMRL. In case of a linear pathway, harvesting values would be higher on average (see Table 11-9) and thus result in a FMRL being more positive because of higher losses in living biomass.

- The exponential pathway better reflects reality than the linear pathway, especially since harvesting rates have declined starting in 2009 due to the worldwide, unforeseen financial crisis.

From this, it is concluded that Switzerland's BAU harvesting scenario is not changed, neither are the policy assumptions. The increase in harvest of on average 30% over the period 2013-2020 compared to 1990-2007 remains as defined in FOEN (2011l). To reach this target, the increase in harvest follows an exponential pathway.

11.7.2.2 Implementation of a stepwise Pathway

Since the model works at an interval-basis, the business-as-usual harvesting scenario has to be translated from a continuous into a stepwise pathway.

For the submission FOEN (2011l), the stepwise pathway of BAU harvesting rates were not correctly implemented: the target value for BAU harvesting rates, was reached already in 2017 and not in 2026, which resulted in an overestimation of the losses in living biomass.

11.7.3 Modelling Changes in Carbon Stocks of Soil Carbon, Dead Wood and Litter

The model Yasso07 has been implemented since Switzerland's GHG inventory 1990-2011 (FOEN 2013) and improvements have been made continuously (see Didion et al. (2013, 2014, 2014a). A major improvement has been the coupling of both models Massimo and Yasso. For a detailed description of the implementation of Yasso07 for the Swiss greenhouse gas inventory see Didion et al. (2012, 2013) and for calculation of Switzerland's FMRL see Didion et al. (2014b).

11.7.4 Calculation of Carbon Stock Changes in HWP

Calculation of carbon stock changes in HWP: carbon stock changes in HWP are calculated following the IPCC methodology (IPCC 2014) which is different from the methodology applied in FOEN (2011l). For the recaclukation of the FMRL exported HWPs from domestic harvest are included and HWPs from deforestation are excluded. Further, the historical time series has been improved and updated (FOEN 2015i).

11.7.5 Emissions from Forest Fires

Since there is no trend in wildfires, the emissions from forest fires for the FMRL is calculated as the average of the emissions over the period 1990-2009 (see Table 6-33). For an average area of 281.05 ha affected by wildfires, emissions of 13.98 kt CO_2 eq. were calculated.

11.7.6 Emissions from organic Soils

Drainage of forests is reported as described in Chapter 6.4.2.11.

- In order to calculate CO_2 emissions due to drainage, we applied the default emission factor of 2.6 t C ha^{-1} yr^{-1} according to the Wetland Supplement (IPCC 2014a, Table 2.1).
- N_2O emissions from drainage of organic soils was calculated for forest land with an emission factor of 2.8 kg N_2O-N ha^{-1}, default value in the Wetlands Supplement (IPCC 2014a, Table 2.5) for temperate forest land.

11.7.7 Calculation of the area under Forest Management in CP2

The area under Forest Management for the period 2013-2020 is calculated by extrapolating the trend from the historical ativity data 1990-2009 (in Table 11-5). The area under FM is stratified per land-use type (productive forest CC12, unproductive forest CC13 and for changes between CC12 and CC13) and per soil type (mineral and organic soils; Table 11-10).

Table 11-10: Mean area under Forest Management for the period 2013-2020 derived from linear extrapolation of historical data 1990-2009 stratified per soiltype.The area under Forest Management is stratified into mineral and organic soils, in productive forest CC12, unproductive forest CC13 and in lands changing between CC12 and CC13 and vice versa (see Chapter 11.2.3).

Mean 2013-2020 (kha)	Productive forest CC12	CC12 to CC13	CC13 to CC12	Unproductive forest CC13
Mineral soils	1134.45	4.15	10.61	89.33
Organic soils	3.40	0.01	0.01	0.10
Total soils	1137.85	4.16	10.62	89.43

Mean emission factors over the period 2013-2020 for living biomass, dead wood, litter and soil carbon for the BAU-scenario with an exponential pathway are summarized in Didion et al. (2014b: Table 5). The emission factor for HWP for 2013-2020 is taken from FOEN (2015i).

These emission factors were than applied for the areas under Forest Management (Table 11-10) in order to calculate total emissions and removals from living biomass, deadwood, litter and soil carbon in Swiss Forests. Further, emissions from drainage of organic soils and emissions from forest fires were considered to calculate the corrected FMRL.

Table 11-11: Mean carbon stock changes (changeC) over the period 2013-2020 for the total area under Forest Management. For the Forest Mangement Reference Level carbon stock changes in living biomass ($changeC_l$), litter ($changeC_h$), dead wood ($changeC_c$) and soil ($changeC_s$; including emissions due to former drainage) are considered plus emissions from forest fires. Negative values indicate a sink, positive values a sink of CO_2.

	Mt CO_2 yr^{-1}	**changeC for FMRL**
$changeC_l$	CC12	-0.40
	CC13	0.00
	CC12/CC13	0.07
	CC13/CC12	0.00
	Total Living Biomass	-0.33
$changeC_h$, $changeC_d$, $changeC_s$	CC12	-0.58
	CC13	0.00
	CC12/CC13	0.01
	CC13/CC12	-0.01
	Total Soil, Litter, Dead Wood	-0.59
$changeC_{HWP}$	CC12	-0.78
Forest Fires	CC12	0.01
Total FMRL		**-1.68**

The technical correction of the FMRL is summarized in Table 11-12. The technical correction equals the difference between the FMRL submitted in February 2011 (FOEN 2011l) and the corrected values for the FMRL and amounts to -1.90 Mt CO_2 eq. yr^{-1}.

Table 11-12: Summary of the technical correction of the FMRL. Values from FMRL as defined in FOEN (2011l) and corrected values (this chapter) are listed per pool or source. Abbreviations as used in Chapter 6.1.3.2.

Mt CO_2 eq yr^{-1}	**FMRL Subm. 2011**	**FMRL corrected April 2015**	**Explenation for TC**
$changeC_l$	0.48	-0.33	Chapter 11.7.2.2
$changeC_h$, $changeC_d$, $changeC_s$	-0.05	-0.59	Chapter 11.7.3
$changeC_{HWP}$	-0.21	-0.78	Chapter 6.11, 11.7.4
Forest Fires	0.00	0.01	Chapter 11.7.5
Total	0.22	-1.68	

11.7.8 Planned Improvements

The models Massimo and Yasso07 are continuously further developed.

For Massimo, it is planned to improve the algorithms and assumptions, the code, the usability and the documentation. The major aspects of the revision, which will be implemented over the coming years, include:

- Detailed review and revision of assumptions and implementation concerning the 5-year time step.
- Flexible implementation of natural mortality: tune mortality at a desired level (i.e. background level for natural disturbances; see Chapter 11.8).

- Verification of allometries used to obtain estimates of whole tree volume and biomass, incl. branches, foliage, and roots.

Planned improvements for Yasso07 include:

- New model parameters which are developed at the Finnish Environment Institute and at Tampere University of Technology
- Quantifying the effect of uncertainty associated with the spatially interpolated temperature and precipitation data on carbon stock changes estimates.

11.8 Natural Disturbances

11.8.1 Application of the provision of natural Disturbances

As indicated in Switzerland's Initial Report (FOEN 2015e), Switzerland intends to apply, in the case of significant magnitude events, the provision of natural disturbances for units of lands under Forest Management during the second commitment period in accordance with decision 2/CMP.7. In cases or events in which emissions from natural disturbances are higher than the nationally established threshold value and all other requirements defined in 2/CMP.7 and IPCC (2014) are met, Switzerland will evaluate and decide whether the effort would be justified to exclude them.

In the inventory year 2013, no natural disturbances causing emissions exceeding the upper confidence interval (background level plus margin) occurred. Thus, no emissions from natural disturbances are excluded for 2013.

11.8.2 Technical Correction of the Background Level and Margin

There is no technical correction of the background level and margin for the inventory year 2013.

11.9 Harvested Wood Products

Methodology, estimates and uncertainties of carbon stock changes in the HWP pools are described in Chapter 6.11. The same methodology is applied for reporting HWP from forest land under UNFCCC and accounting for HWP from Forest Management under KP. A time series for changes in the HWP-pool is shown in Table 6-34 and Figure 6-9. HWPs originating from wood harvested at land converted from forest land to non forest land (UNFCCC) or from Deforestations (KP) are not taken into account.

Results are summarized in Table 11-4 and Figure 11-1.

11.10 Information Relating to Article 6

Switzerland does not host Joint Implementation projects.

12 Information on Accounting of Kyoto Units

12.1 Background Information

The Swiss Emissions Trading Registry completed the go-live process and got fully operational with the International Transaction Log (ITL) on December 4, 2007. As part of the go-live process the entire Assigned Amount of 242'838'402 has been issued as AAUs for the first commitment period.

The user interface is located on the Swiss Emissions Trading Registry website (https://www.emissionsregistry.admin.ch). Switzerland uses the CR registry software, which has been developed by Lippke & Wagner GmbH and cooperates with Monaco by hosting the Registry of this Party on Swiss servers. However, both national registries are maintained as independent systems with independent registry administrators.

The following registry systems' reporting includes the standard electronic format (SEF) tables and the standard independent assessment report (SIAR) tables in accordance with sections E and G of the annex to decision 15/CMP.1.

12.2 Summary of Information Reported in the SEF Tables

The Standard Electronic Format reports for units with applicable commitment period 1 (CP1) for 2014, as well as for units with applicable commitment period 2 (CP2) for 2013 and 2014, have been submitted to the UNFCCC Secretariat electronically.

Overview of CP1 units

By the end of the reporting year 2014 a total balance of 253,788,003 Assigned Amount Units (AAUs) were held in the Swiss Emissions Trading Registry (Table 12-1), which represents an increase of approximately 5 million units compared to 2013. From the initial assigned amount of 242,838,402 AAUs, 16,871,232 units have been allocated to companies participating in the Swiss Emissions Trading System in the first commitment period 2008-2012. 13,204,628, of those allocated units, 69,679 ERUs, and 1,806,720 CERs have been surrendered by companies by the end of 2014.

27,637,173 Emission Reduction Units (ERUs) were held in the Swiss Emissions Trading Registry, a significant reduction of approx. 22.3 Mio. units compared to the previous reporting year. The amount of Certified Emission Reductions (CERs) has also decreased by approximately 7.7 Mio units. The amount of tCERs has remained constant. A total of 128,586 AAUs, 116,253 ERUs, 1,760,680 CERs, and 8,098 tCERs have been voluntarily cancelled in the period from 2008 to 2014.

Table 12-1 Total quantities of CP1 Kyoto Protocol units by account type at the end of 2014 (SEF table 4)

Party	CH
Submission Year	2015
Reported Year	2014
Commitment Period	1

Table 4. Total quantities of Kyoto Protocol units by account type at end of reported year						
Account type	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Party holding accounts	242'650'590	558'645	8'652'013	17'286'778	NO	NO
Entity holding accounts	10'836'240	26'962'275	NO	17'598'412	106'695	NO
Article 3.3/3.4 net source cancellation accounts	172'587	NO	628'867	NO		
Non-compliance cancellation account	NO	NO	NO	NO		
Other cancellation accounts	128'586	116'253	NO	1'760'680	8'098	NO
Retirement account	NO	NO	NO	NO	NO	NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
lCER replacement account for expiry	NO	NO	NO	NO		
lCER replacement account for reversal of storage	NO	NO	NO	NO		NO
lCER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	253'788'003	27'637'173	9'280'880	36'645'870	114'793	NO

Overview of CP2 units

By the end of the reporting year 2013 a total balance of 231,622 CERs were held in the Swiss Emissions Trading Registry (Table 12-2). By the end of the reporting year 2014, this number has increased to 3,710,907 CERs, of which 31,122 CERs have been cancelled (Table 12-3).

Table 12-2 Total quantities of CP2 Kyoto Protocol units by account type at the end of 2013 (SEF table 4)

Party	CH
Submission Year	2014
Reported Year	2013
Commitment Period	2

Table 4. Total quantities of Kyoto Protocol units by account type at end of reported year						
Account type	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Party holding accounts	NO	NO	NO	NO	NO	NO
Entity holding accounts	NO	NO	NO	231'622	NO	NO
Retirement account	NO	NO	NO	NO	NO	NO
Previous period surplus reserve account	NO					
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation account	NO	NO	NO	NO		
Voluntary cancellation account	NO	NO	NO	NO	NO	NO
Cancellation account for remaining units after carry-over	NO	NO	NO	NO	NO	NO
Article 3.1 ter and quater ambition increase cancellation account	NO					
Article 3.7 ter cancellation account	NO					
tCER cancellation account for expiry					NO	
lCER cancellation account for expiry						NO
lCER cancellation account for reversal of storage						NO
lCER cancellation account for non-submission of certification report						NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
lCER replacement account for expiry	NO	NO	NO	NO		
lCER replacement account for reversal of storage	NO	NO	NO	NO		NO
lCER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	NO	NO	NO	231'622	NO	NO

Table 12-3 Total quantities of CP2 Kyoto Protocol units by account type at the end of 2014 (SEF table 4)

Party	CH
Submission Year	2015
Reported Year	2014
Commitment Period	2

Table 4. Total quantities of Kyoto Protocol units by account type at end of reported year						
Account type	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Party holding accounts	NO	NO	NO	NO	NO	NO
Entity holding accounts	NO	NO	NO	3'679'785	NO	NO
Retirement account	NO	NO	NO	NO	NO	NO
Previous period surplus reserve account	NO					
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation account	NO	NO	NO	NO		
Voluntary cancellation account	NO	NO	NO	31'122	NO	NO
Cancellation account for remaining units after carry-over	NO	NO	NO	NO	NO	NO
Article 3.1 ter and quater ambition increase cancellation account	NO					
Article 3.7 ter cancellation account	NO					
tCER cancellation account for expiry					NO	
lCER cancellation account for expiry						NO
lCER cancellation account for reversal of storage						NO
lCER cancellation account for non-submission of certification report						NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
lCER replacement account for expiry	NO	NO	NO	NO		
lCER replacement account for reversal of storage	NO	NO	NO	NO		NO
lCER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	NO	NO	NO	3'710'907	NO	NO

12.3 Discrepancies and Notifications

Switzerland's reports on discrepancies (R-2), CDM notifications (R-3), non-replacements (R-4) including reversal of storage and failure of certification and invalid units (R-5) have been uploaded on the UNFCCC Submission Portal.

During the reported year 2014, the Swiss Emissions Trading Registry had one discrepant transaction with the DES code 4003, no CDM notifications, no non-replacements including reversal of storage and failure of certification and no invalid units. The discrepant transaction has been reported in the SIAR table R-2.

12.4 Publicly Accessible Information

In accordance to section E of the annex to decision 13/CMP.1 the Swiss Emissions Trading Registry makes non-confidential information available to the public via webpage or user-interface.

Non-confidential information is publicly available on the Swiss Emissions Trading Registry website https://www.emissionsregistry.admin.ch. The national allocation plan is accessible under 'Allocation' in the Publis Reports menu. The report 'Accounts' provides a list of open accounts in the national registry. The 'Surrendering Obligation', and 'Surrendered units' per operator are also publicly accessible.

Data of transfers and holdings of individual accounts are considered as business secrets and the disclosure may prejudice their competitiveness. Information on acquiring and transferring units of companies (as legal persons) is therefore regarded as personal data. Article 19 of the Federal Act on Data Protection (FADP, SR 235.1 Bundesgesetz vom 19. Juni 1992 über den Datenschutz (DSG) 2) enacts that federal bodies may disclose personal data if there is a legal basis for doing so or if there is an overriding public interest. In the present case these conditions are not fulfilled. Therefore, the registry of Switzerland cannot make the information on acquiring and transferring accounts publicly available and considers them as confidential. A statement on which information is considered as confidential can be found on the public website https://www.emissionsregistry.admin.ch.

All other information referred to in paragraphs 44 to 48 to the annex to decision 13/CMP.1 are made publicly available by the Swiss Emissions Trading Registry, if they are not covered by the above mentioned articles.

Information related to Article 6 projects is publicly accessible on the website http://www.bafu.admin.ch/ji-e. Switzerland does not host JI-projects and therefore no issuance of ERUs has taken place.

12.5 Calculation of the Commitment Period Reserve (CPR)

The commitment period reserve and the assigned amount for the second commitment period will be defined in the *Report to facilitate the calculation of the assigned amount pursuant to Article 3, paragraphs 7bis, 8 and 8bis, of the Kyoto Protocol for the second commitment period 2013 - 2020 (Switzerland's Initial Report under the Kyoto Protocol, 2nd CP).* This report will be submitted later in 2015 (FOEN 2015e).

12.6 KP-LULUCF Accounting

According to the 'Report of the individual review of the annual submission of Switzerland submitted in 2013' (UNFCCC 2014c), Switzerland cancelled 139,278 Removal Units (RMUs) for its Deforestation activities into its Net Source Cancellation account (ITL notification ID: 1000380013), and subsequently issued 54,384 RMUs for its Afforestation and Reforestation activities, and 6,522,301 RMUs for its Forest Management activities in its Emissions Trading Registry. The transactions took place on 21 March 2014 (cancellation), and 11 November 2014 (issuance) respectively.

13 Information on Changes in National Registry

Table 13-1 Changes in the national registry in accordance with §32 decision 15/CMP.1

Annual Submission Item	Reporting
15/CMP.1, Annex II, paragraph 32(a): Change of name or contact	Main contact: Mr. Matthias Kohler Phone: +41 31 322 92 52 matthias.kohler@bafu.admin.ch
15/CMP.1, Annex II, paragraph 32(b): Change of cooperation arrangement	No change of cooperation arrangement occurred during the reported period. Switzerland continues to cooperate with Monaco and hosts the registry of Monaco on Swiss servers. However, the two national registries are maintained as independent systems with independent registry administrators.
15/CMP.1, Annex II, paragraph 32(c): Change to database or the capacity of national registry	The following relevant changes occurred during the reporting year: • New registry operating system platform and database • New registry hardware infrastructure • New registry software provider • New registry software In April 2014, all relevant changes have been reported to the International Transaction Log (ITL) in an updated Registry Initialization Documentation and Readiness Questionnaire including the following documents or sections: • Database and application backup plan • Disaster recovery plan • Test plan • Test report Based on the test reports and supporting documentation provided, Switzerland has successfully passed readiness review and was able to switch to 'Full Operation' with the new registry environment on 22 April 2014. A more detailed documentation is not provide here, because the respective information is regarded as confidential. However, it can be made available to the ERT upon approval of a specific request.
15/CMP.1, Annex II, paragraph 32(d): Change of conformance to technical standards	In January 2014, the new registry software successfully passed the Annex H test and therewith conforms to the technical standards as specified in the UNFCCC Data Exchange Standards for registry systems under the Kyoto Protocol, technical design specification, version 1.1.10. In April 2014, all relevant changes have been reported to the ITL in an updated Registry Initialization Documentation and Readiness Questionnaire including the following documents or sections: • Version change management • Test plan • Test report Based on the test reports and supporting documentation provided, Switzerland has successfully passed readiness review and was able to switch to 'Full Operation' with the new registry environment on 22 April 2014. A more detailed documentation is not provide here, because the respective information is regarded as confidential. However, it can be made available to the ERT upon approval of a specific request.
15/CMP.1, Annex II, paragraph 32(e): Change of discrepancies procedures	In April 2014, all relevant changes have been reported to the ITL in an updated Registry Initialization Documentation and Readiness Questionnaire including the following documents or sections: • Operational plan • Test plan • Test report Based on the test reports and supporting documentation provided, Switzerland has successfully passed readiness review and was able to switch to 'Full Operation' with the new registry environment on 22 April 2014. Experience shows that the changes led to a significant decrease in number of discrepancies and problems as well as the time to resolve any incidents. A more detailed documentation is not provide here, because the respective information is regarded as confidential. However, it can be made available to the ERT upon approval of a specific request.
15/CMP.1, Annex II, paragraph 32(f): Change of security	In April 2014, all relevant changes have been reported to the ITL in an updated Registry Initialization Documentation and Readiness Questionnaire including the following documents or sections: • Security plan • Operational plan Based on the test reports and supporting documentation provided, Switzerland has successfully passed readiness review and was able to switch to 'Full Operation' with the new registry environment on 22 April 2014. In October 2014, the registry software was updated to further increase the security of the software administration. A more detailed documentation is not provide here, because the respective information is regarded as confidential. However, it can be made available to the ERT upon approval of a specific request.

Table continued: Changes in the national registry in accordance with §32 decision 15/CMP.1

Annual Submission Item	Reporting
15/CMP.1, Annex II, paragraph 32(g): Change of list of publicly available information	In accordance to section E of the annex to Decision 13/CMP.1, the Swiss Emissions Trading Registry makes non-confidential information available to the public via website or user interface. In October 2014, the publicly available information was consolidated on the registry's website (https://www.emissionsregistry.admin.ch) to further improve accessibility and user-friendliness. Information on JI projects, pursuant to paragraph 46 of the annex to Decision 13/CMP.1 is publicly available on the FOEN website (http://www.bafu.admin.ch/ji-e). Information on unit holding and transactions for each calendar year, pursuant to paragraph 47 of the annex to Decision 13/CMP.1 is publicly available in the SEF tables on the FOEN website (http://www.bafu.admin.ch/ghginv).
15/CMP.1, Annex II, paragraph 32(h): Change of Internet address	The new internet address of the registry is https://www.emissionsregistry.admin.ch.
15/CMP.1, Annex II, paragraph 32(i): Change of data integrity measures	In April 2014, all relevant changes have been reported to the ITL in an updated Registry Initialization Documentation and Readiness Questionnaire including the following documents or sections: • Application logging documentation • Disaster recovery plan • Test plan • Test report Based on the test reports and supporting documentation provided, Switzerland has successfully passed readiness review and was able to switch to 'Full Operation' with the new registry environment on 22 April 2014. A more detailed documentation is not provide here, because the respective information is regarded as confidential. However, it can be made available to the ERT upon approval of a specific request.
15/CMP.1, Annex II, paragraph 32(j): Change of test results	See list of submitted items above.

14 Information on Minimization of Adverse Impacts in Accordance with Article 3, Paragraph 14

The Convention (Art. 4 §8 and §10) and its Kyoto Protocol (Art. 2 §3 and Art. 3 §14) commit Parties to strive to implement climate policies and measures in such a way as to minimize adverse economic, social and environmental impacts on developing countries when responding to climate change.

Context

Switzerland strives to design climate change policies and measures in a way as to ensure a balanced distribution of mitigation efforts by implementing climate change response measures in all sectors and for different gases. Indirectly, this approach is deemed to minimize also the scope of potential adverse impacts on concerned actors (including developing countries). Though, due to Switzerland's size and share related to international trade – mainly concentrated on the EU – and greenhouse gas emissions, it is not assumed that Swiss climate change policies have any significant adverse economic, social and environmental impacts in developing countries. Additionally, the policies and measures are very much compatible and consistent with those of the European Union in order to avoid trade distortion, non-tariff barriers to trade and to set similar incentives. All major projects of law in Switzerland are accompanied by impact assessments, inter alia including evaluation of trade-related issues. In accordance with international law, this approach strives at ensuring that Switzerland is implementing those climate change response measures, which are least trade distortive and do not create unnecessary barriers to trade. Consistently, Switzerland notifies all proposed non-tariff measures having a potential impact on trade to the WTO, where specific concerns can be raised by other parties. Moreover, Switzerland belongs to the most important donors in the area of Aid for Trade.

The impact assessment is accompanied by a broad internal and external consultation process, inter alia inviting competent actors to provide advice on international economic, social and environmental aspects of proposed policies and measures. The open public consultation process, together with regular policy dialogues with other countries guarantee that all domestic and foreign stakeholders can raise concerns and issues about new policy initiatives, i.e. including those concerns about possible adverse impacts on other countries.

Progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse-gas-emitting sectors, taking into account the need for energy price reforms to reflect market prices and externalities

Environmental policy in Switzerland, including climate change policies, are guided by the "polluter pays" principles, as enshrined in the Federal Law on the Protection of the Environment. Accordingly, the internalization of external costs and adequate price signals are key aspects of Switzerland's climate change policy. Regarding greenhouse gas emissions, market-based instruments, such as the Swiss Emissions Trading Scheme, the supplemental use of Certified Emission Reductions from the Clean Development Mechanism or the levy for heating and process fuels are important measures to put a price on emissions of greenhouse gases (see Sixth National Communication for more details), that are then reflected in market prices and thus internalizing externalities.

Fiscal incentives, tax and duty exemptions and subsidies

Price-based measures are recognized as essential instruments for promoting the efficient use of resources and to reduce market imperfections. In 2001 Switzerland introduced a heavy vehicle fee (HVF). It is applied to passenger and freight transport vehicles of more than 3.5 tonnes gross weight. The impact of the HVF introduction was most clearly reflected by changes in traffic volume (truck-kilometres) but also in reduced air pollution, a renewal of the heavy vehicle fleet and an increase of load per vehicle, fewer trucks having transported more goods. Two thirds of the revenues are used to finance major railway infrastructure projects (such as the two base tunnels through the Alps), and one third is transferred to the cantons.

In 2008 Switzerland introduced a CO_2 levy on heating and process fuel to set an incentive for a more efficient use of fossil fuels, promote investment in energy-efficient technologies and the use of low-carbon or carbon-free energy sources. The 2013 amendment to the CO_2 act (Swiss Confederation 2012) still encompasses the imposition of a CO_2 levy on heating and process fuel. Companies, especially those industries with substantial CO_2 emissions from use of heating fuels, may apply for exemption from the CO_2 levy, provided the company commits to emission reductions. The company has to elaborate an emission reduction target, based on the technological potential and economic viability of various measures within the company. While the proceeds from the CO_2 levy were initially to be fully and equally refunded to the Swiss population and to the business community in proportion of wages paid, a parliamentary decision of June 2009 earmarked a third of the revenues from the CO_2 levy to CO_2 relevant measures in the building sector (Building refurbishment programme). The partial earmarking of revenues from the CO_2 tax is limited in the revised CO_2 act to a maximum of 300 million Swiss francs per year.

The economic impact of the Swiss climate policy was analysed in two studies[14]. The impact is considered to be very small.

Switzerland does not subsidize fossil fuels in general. There are some minor schemes in place though that may be regarded as fossil fuel subsidies. In international comparison, however, these schemes are limited: At the federal level, a few tax exemptions and reductions provide some form of support to users of fossil fuels. Farmers, foresters, fishermen and the fuel use of snow cats are exempt from the mineral oil tax that is normally levied on sales of mineral oils, while public transport companies benefit from a reduced rate. Some vehicles are also exempt from the performance-related Heavy Vehicle Fee (HFV), e.g. agricultural vehicles, vehicles used for the concessionary transport of persons or vehicles for police, fire brigade, oil and chemical emergency unit, civil protection and ambulances.

[14] Ecoplan (2009): Volkswirtschaftliche Auswirkungen der Schweizer Post-Kyoto-Politik, im Auftrag des BAFU. BAFU (2010): Synthesebericht zur Volkswirtschaftlichen Beurteilung der Schweizer Klimapolitik nach 2012.

The need for energy prices reforms

World-wide subsidies for fossil fuels are estimated at 300-500 billion USD per annum, depending on the level of energy prices. This huge market distortion does not only produce severe fiscal problems for the countries concerned, it is also a major obstacle for enhanced investments in energy efficiency measures and renewable energies.

Switzerland as a member of the Friends of Fossil Fuels Subsidies Reform group supports the gradual and sustained reduction of unnecessary market-distortions. Switzerland under its Economic Development Cooperation supports partner countries in the design and implementation of energy tariff reforms, as an element of infrastructure financing programs. Switzerland has been an initiator of specialized international programs, including the World Bank's Energy Sector Management Program ESMAP. The Energy Efficiency Governance Handbook has been produced with Swiss financing (IEA/EBRD 2010).

Removing subsidies associated with the use of environmentally unsound and unsafe technologies

Switzerland doesn't subsidize the use of environmentally unsound and unsafe technologies.

Strengthening the capacity of developing country Parties for improving efficiency in upstream and downstream activities relating to fossil fuels, taking into consideration the need to improve the environmental efficiency of these activities

Switzerland supports through different projects the enhancement of efficiency in industrial production, i.e. "cleaner production". These cleaner production projects promote eco-efficient means of production and better working conditions attained through technical improvements and behavioural changes in both management and staff in industrial companies and services. The resulting rise of economic and environmental efficiency and improved competitiveness is gained through the systematic optimisation of energy use, processing of raw material, more efficient use of resources and thus better protection of the environment.

Furthermore, there is a rising awareness and demand by consumers for environmentally sound products. In order to alleviate potential adverse economic impacts of corresponding national measures Switzerland promotes and supports the development of international standards, especially with regard to the sustainable use of natural resources (including agricultural commodities), e.g. through the creation of sustainability standards, financial incentives and favourable framework conditions in developing countries by consultancy services and technology transfer. Further information is contained in Chapter 7 of Switzerland's Sixth National Communication (FOEN 2014d).

Assisting developing country Parties which are highly dependent on the export and consumption of fossil fuels in diversifying their economies

Most developing and transition countries have, in recent years, taken important steps towards trade liberalisation, in order to align their trade policies with multilateral trade agreements. The Swiss State Secretariat for Economic Affairs (SECO) supports these efforts, because a multilaterally acknowledged and respected set of regulations for international transactions not only strengthens trade as such, but also creates more potent and legally secure markets to the benefit of all players.

The measures taken by SECO are aimed at creating the necessary conditions for earning additional income in the beneficiary countries and thereby contribute directly to the alleviation of poverty. SECO is focusing on three areas of intervention along the value chain: (i) International competitiveness (ii) Enabling framework conditions for trade (iii) Improving market access.

For example market access: Trade between developing and industrial countries is still insufficiently developed respectively not diversified enough. On one hand, the developing countries lack the necessary production capacities, transport infrastructure and know-how; on the other hand, tariff and non-tariff barriers to trade make direct access to markets more difficult.

Switzerland promotes access to Swiss markets by granting preferential tariffs on products from developing and emerging countries. In addition, SECO runs programmes for promoting imports to Switzerland and the rest of Europe. The easing of market entry for products from disadvantaged countries is an important contribution to the promotion and diversification of trade, the increase of export revenues and thus to the economic development of the partner countries. Switzerland supports developing and transition countries in the following areas:

- Generalized system of preferences (GSP)
- Swiss Import Promotion Program (www.sippo.ch)
- Development of new private voluntary social and environmental standards based on international multi-stakeholder approaches: private sustainability standards Better Cotton, 4C (Common Code for the Coffee Community), Roundtable for Sustainable Biofuels, etc.

Finally, Switzerland is a strong supporter of the EITI (Extractive Industries Transparency Initiative). We share a belief that the rational use of natural resource wealth is an important driving force for sustainable economic growth that contributes to sustainable development and poverty reduction. The sustainable management of natural resource wealth – as supported by EITI principle and criteria incl. regular publication and audit of revenues – is key to mobilize the funds for diversification strategies.

Changes compared to the latest submission

There are no changes compared to the 2014 submission.

15 Other Information

This chapter contains Switzerland’s response to the Saturday Paper (UNFCCC 2014d). Together with this response, Switzerland has also made a resubmission of the CRFs to the UNFCCC in November 2013 (FOEN 2014m):

Inventory related potential problems

Annex A categories

With reference to the Guidelines for review under Article 8 of the Kyoto Protocol, the ERT requests that additional information and/or revised estimates for the 2012 greenhouse gas (GHG) inventory corresponding to the potential problems identified in this paper (see attached tables) be forwarded to the ERT, through the UNFCCC secretariat, not later than by 20 October 2014.

Should Switzerland decide to submit by 20 October 2014, in response to some or all potential problems, revised estimates of its GHG emissions, the ERT requests that the revised estimates contain the following:

- Relevant background information and a descriptive summary of the revisions made by Switzerland in its 2014 annual submission, in particular in the year 2012 or years 2008-2012 with respect to CH_4 and N_2O emissions from the following sectors and categories
- Energy sector:
    - CH_4 and N_2O emissions from manufacturing industries and construction, stationary combustion of LPG (1.A.2) and from other sectors, commercial / institutional (1.A.4.a) (2008-2012),
    - CH_4 emissions from other sectors, residential (1.A.4.b) (2008-2012),
    - N_2O emissions from other sectors, residential (1.A.4.b) (2008-2012),
    - Fugitive emissions from natural gas, transmission (1.B.2.b(iii)) and other leakage (1.B.2.b(v)) (2008-2012).
- Waste sector:
    - CH4 emissions from solid waste handling on land (6.A)
- A complete resubmission of the 2014 CRF tables, reflecting the revised estimates;
- Party’s revision of the calculation of the commitment period reserve, based on the recalculated emissions reported in the 2014 annual submission, if the calculation of the commitment period reserve is based on the inventory and not the assigned amount.

ATTACHMENT A

Overview of inventory potential problems identified for 2008-2012

Annex A sources

2014 GHG inventory review

Switzerland

Abbreviations:

GPG: IPCC good practice guidance

AD: activity data, EF: emission factor, IEF: implied emission factor

KC: key category, ERT: Expert Review Team

Sector, category, sub-category (with code)	Gas	KC/non-KC	Identified inventory problem in terms of:		
			Missing estimate	Estimate provided but not in line with GPG	Estimate provided but lack of transparency
Energy, manufacturing industries and construction (1.A.2), other sectors, commercial / institutional (1.A.4.a)	CH_4, N_2O	**non-KC**		X	

Description of problem identified:

Until the 2014 submission, Switzerland reported emissions from LPG in association with emissions from gas oil as the Party was unable to discriminate the two fuels used under manufacturing industries and construction (1.A.2) and commercial (1.A.4.a). In the 2014 submission, Switzerland reported disaggregated CH4 and N2O emissions from these two fuels for the first time.

Switzerland has estimated emissions of CH4 and N2O from liquefied petroleum gas (LPG) using the default tier 1 emission factors (EFs) reported in the *2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories* (hereinafter referred as the 2006 IPCC Guidelines). The values of the default tier 1 EFs in the 2006 IPCC Guidelines are 1 kg CH4/TJ and 0.1 kg N2O/TJ while the corresponding values in the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (hereinafter referred as the Revised 1996 IPCC Guidelines) are higher, namely 2 kg CH4/TJ and 0.6 N2O/TJ.

In its responses to questions raised by the ERT during the review, Switzerland indicated that the Party considers that the tier 1 default EFs in the 2006 IPCC Guidelines are most appropriate because they provide specific values for LPG.

The ERT is of the view that the Revised 1996 IPCC Guidelines contains tier 1 values that are applicable to any oil derived product, such as LPG, and notes that Lead Reviewers in their sixth meeting have clearly indicated that when Parties use new information from the 2006 IPCC Guidelines or elsewhere that leads to lower emissions estimates than in previous submissions, the ERT should ensure that the Party justify in its annual submission the use of this new information in accordance with the GPG. Furthermore, the ERT notes that GPG considers the split by fuel as a tier 1 approach for non-CO2 gases while for a tier 2 approach, the split by technologies is required.

The ERT is of the view that by choosing the default tier 1 EFs in the 2006 IPCC Guidelines with no other information supporting the claim that LPG is not individually covered in the Revised 1996 IPCC Guidelines is not in line with the GPG. Furthermore, Switzerland is potentially underestimating CH4 and N2O emissions that occurred during the first commitment period of the Kyoto Protocol (CP1) since the Revised 1996 IPCC Guidelines constitute the basis of the agreed methodologies to estimate emissions and removals for this period (decision 2/CP.3).

Recommendation by ERT:

The ERT recommends that Switzerland:

(1) provide technology-based information that justifies that emissions of CH4 and N2O arising from the combustion of LPG using current technologies and practices in Switzerland are best represented by the tier 1 default EFs provided by the 2006 IPCC Guidelines.

If Switzerland is unable to provide the information described in item 1 above, and the only data available regarding these emission estimates are the amount of LPG combusted, then the ERT recommends that Switzerland:

(2) estimate CH4 and N2O emissions using the tier 1 default EFs provided in the Revised 1996 IPCC Guidelines. In this case, the ERT further recommends that Switzerland submit revised estimates for the whole time series in the CRF tables.

Response / Information by Party:

There is no technology-based information available. Therefore, the emission factor for CH4 and N2O for combustion of LPG has been changed to the values provided in table 1-7 and 1-8 in the Revised 1996 IPCC Guidelines. The corresponding EF in the 1996 GLs are 2 kg CH4/TJ and 0.6 kg N2O/TJ.

Please note that LPG is used in sector 1A2 only. The statement made during the review, that LPG was also used in sector 1A4a is wrong (see NIR table 3-43 for a disaggregation of the different fuels used in sector 1A4a). Therefore, the recalculation is made in sector 1A2 only.

This results in the following changes to the emissions in sector 1A2, liquid fuels:

		1990	2008	2009	2010	2011	2012
April 2014	CH4 (Gg)	0.11	0.06	0.06	0.06	0.05	0.05
	N2O (Gg)	0.04	0.04	0.04	0.04	0.04	0.04
Revised	CH4 (Gg)	0.11	0.06	0.06	0.06	0.05	0.05
	N2O (Gg)	0.05	0.04	0.04	0.04	0.04	0.04
Difference	CH4 (Gg)	0.004	0.004	0.005	0.004	0.004	0.004
	N2O (Gg)	0.002	0.002	0.002	0.002	0.002	0.002
Total difference	**CO2eq (Gg)**	**0.8**	**0.8**	**0.8**	**0.7**	**0.7**	**0.7**

Potential problem unsolved? Rationale:

Resolved. Switzerland recalculated the emissions in accordance with the recommendation by the ERT. In particular, the Party applied the second option in the recommendation.

Overview of inventory potential problems identified for 2012

Annex A sources

2014 GHG inventory review

Switzerland

Abbreviations:

GPG: IPCC good practice guidance

AD: activity data, EF: emission factor, IEF: implied emission factor

KC: key category, ERT: Expert Review Team

Sector, category, sub-category (with code)	**Gas**	**KC/non-KC**	**Identified inventory problem in terms of:**		
			Missing estimate	**Estimate provided but not in line with GPG**	**Estimate provided but lack of transparency**
Energy, other sectors, residential (1.A.4.b)	CH_4	**KC, trend**		X	

Description of problem identified:

The EFs used by Switzerland to estimate CH4 emissions from wood combustion under residential (1.A.4.b) are based on measurements of volatile organic components (VOC) of a series of wood combustion plants at various conditions. The CH4 EFs are then calculated using a factor α of 0.3 (α=CH4/VOC) based on measurements in log wood stoves and boilers.

Switzerland has obtained this type of technology-based CH4 EFs for 1990 and 2008 for 16 technologies. For all technologies, CH4 EFs in 2008 are lower than those in 1990. Switzerland estimates the CH4 EFs for the years between 1991 and 2007 as linear interpolation of the values in 1990 and 2008, obtaining a linearly decreasing time series of CH4 EFs. During the review, Switzerland indicated that this trend is also in line with the Swiss air pollution control policy with increased requirements since 2007. In this regard, the ERT notes that it is unlikely that the values between 1990 and 2006 be in line with a control policy enacted in 2007.

In a similar way, CH4 EFs for the period 2008-2012 are estimated on the basis of a modelled CH4 EF in 2035, by interpolation between the measured CH4 EF in 2008 and the modelled CH4 EF in 2035, generating a series of annually decreasing CH4 EFs. During the review, Switzerland indicated that this model assumes that in 2035, all installations will be of currently best available technologies (as of 2010). During the review, Switzerland provided the ERT with the specific reference used for this estimation and spread sheets showing all the values of CH4 EFs for 1990, 2008 and 2035 and indicated that, based on the provided information, the Party is convinced that a linear decrease in Swiss CH4 EF model between 1990, 2008 and 2035 is justified.

The ERT consulted the Swiss air pollution control policy and did not find enough evidence of programmed annual retirement of old units and annual incorporation of best available technologies to justify (1) the linear interpolation between the values in 1990 and 2007 and (2) the modelled scenario for 2035.

In page 7.21, the GPG indicates:

In some cases, it may be necessary to develop a customised approach in order to best estimate the emissions over time. For example, the standard alternatives may not be valid when technical conditions are changing throughout the time series (e.g. due to the introduction of mitigation technology). In this case, revised emission factors may be needed and it will also be necessary to carefully consider the trend in the factors over the period. Where customised approaches are used, it is good practice to document them thoroughly, and in particular to give special consideration to how the resultant emissions estimates compare to those that would be developed using the more standard alternatives.

The ERT is of the view that the linear interpolation between the measured CH4 EFs in 2008 and the modelled CH4 EF in 2035, whose derivation has not been documented thoroughly by the Party, is not in line with GPG. The ERT further notes that a linear interpolation between two values separated by 27 years is questionable. The ERT considers that the use of annually decreasing series of CH4 EFs between 2008 and 2035 leads to a potential underestimation of CH4 emissions during the first commitment period of the Kyoto Protocol.

Recommendation by ERT:

The ERT recommends that Switzerland provide thorough documentation to justify its approach to develop the CH4 EFs, including the annual rate of retirement of old units and the incorporation of new technologies.

If Switzerland cannot provide this documentation, the ERT recommends that Switzerland estimate CH4 emissions from wood under residential for all years of the CP1 using the CH4 EFs obtained for 2008. The ERT further recommends that Switzerland provide revised estimates for the whole time series in the CRF tables.

Response / Information by Party:

The country-specific technology-based CH4 EFs are available for 1990 and 2008. For 1990, the values remain unchanged, as the CH4 EFs were determined specifically for that year and reflect the status of 1990. For the entire commitment period 2008-2012, the CH4 EFs for 2008 are used (compared to the interpolation of the EFs between 2008 and 2035).

For the period 1991-2007, the data in the revised CRF tables is unchanged compared to the submission of April 2014. A more detailed investigation into the temporal development of the emission factors and the technology implementation for the period 1991-2007 will be discussed in the greenhouse gas inventory core group and would then feed into the routine inventory development cycle (inventory development plan).

This results in the following recalculations for biomass in sector 1A4b:

		1990	2008	2009	2010	2011	2012
April 2014	Gg CH4	4.66	1.95	1.84	1.92	1.53	1.61
Revised	Gg CH4	4.66	1.95	1.86	1.97	1.58	1.69
Difference	Gg CH4	0.00	0.00	0.02	0.05	0.06	0.08
Total difference	**Gg CO2eq**	**0.00**	**0.00**	**0.47**	**1.01**	**1.22**	**1.76**

Potential problem unsolved? Rationale:

Resolved. Switzerland recalculated the emissions in accordance with the recommendation by the ERT.

Overview of inventory potential problems identified for 2012

Annex A sources

2014 GHG inventory review

Switzerland

Abbreviations:

GPG: IPCC good practice guidance

AD: activity data, EF: emission factor, IEF: implied emission factor

KC: key category, ERT: Expert Review Team

Sector, category, sub-category (with code)	**Gas**	**KC/non-KC**	**Identified inventory problem in terms of:**		
			Missing estimate	**Estimate provided but not in line with GPG**	**Estimate provided but lack of transparency**
Energy, other sectors, residential (1.A.4.b)	N_2O	**Non-KC**		X	

Description of problem identified:

The N2O EF (1.6 kg/TJ) for wood combustion under residential of the Swiss national greenhouse gas emission inventory is the lowest among reporting Parties through the entire reporting years and lower than the tier 1 default value reported in the Revised 1996 IPCC Guidelines (4 kg/TJ).

During the review, Switzerland informed the ERT that based on a couple of available measurements in the literature with N2O EF values in the range 0.3 – 8 kg/TJ, experts have suggested 2 kg/TJ and 6 kg/TJ as most reasonable values for wood and wood waste combustion, respectively. On this basis, the Party has decided to use the tier 1 IPCC default value of 4 kg/TJ from the 2015 submission onwards.

The ERT considers that the use of the value of 1.6 kg/TJ to estimate N2O emissions from wood combustion without supporting information for this choice leads to an underestimation of these emissions throughout the entire time series. Furthermore, the view of the ERT is confirmed by the decision by Switzerland to change this EF for the 2015 submission.

Recommendation by ERT:

The ERT recommends that Switzerland estimate N2O emissions from wood under residential for all years between 1990 and 2012 using the tier 1 IPCC default value of 4 kg/TJ. The ERT further recommends that Switzerland provide revised estimates for the whole time series in the CRF tables.

Response / Information by Party:

The N2O emission factor for wood combustion under residential (1A4b) has been changed to the default EF for N2O of 4 kg/TJ.

This results in the following recalculations for biomass in sector 1A4b:

		1990	2008	2009	2010	2011	2012
April 2014	Gg N2O	0.03	0.03	0.03	0.03	0.03	0.03
Revised	Gg N2O	0.09	0.07	0.07	0.08	0.07	0.07
Difference	Gg N2O	0.05	0.05	0.04	0.05	0.04	0.04
Total difference	**Gg CO2eq**	**16.4**	**14.0**	**13.9**	**15.2**	**12.6**	**13.8**

Potential problem unsolved? Rationale:

Resolved. Switzerland recalculated the emissions in accordance with the recommendation by the ERT. In particular, the Party applied the second option in the recommendation.

Overview of inventory potential problems identified for 2008-2012

Annex A sources

2014 GHG inventory review

Switzerland

Abbreviations:

GPG: IPCC good practice guidance

AD: activity data, EF: emission factor, IEF: implied emission factor

KC: key category, ERT: Expert Review Team

Sector, category, sub-category (with code)	Gas	KC/non-KC	Identified inventory problem in terms of:		
			Missing estimate	Estimate provided but not in line with GPG	Estimate provided but lack of transparency
Energy, natural gas, transmission (1.B.2(iii)) and other leakage (1.B.2(v))	CH_4	**KC, level and trend**	X		

Description of problem identified:

(1) Mistake in the estimation of CH4 emissions from natural gas transmission in 2012

Switzerland indicates in its national inventory report (NIR) that an error in the CH4 EF of natural gas pipelines has been detected during the internal review and that this error has led to an underestimation of the emissions based on a too low emission factor used for the calculation. Switzerland further indicates that the error will be corrected for the next submission.

During the review, Switzerland informed the ERT that the emission factor for transit pipelines was erroneously assumed equal to high-pressure steel cathode protected and that the revised estimate for transmission losses (based on the correct EF) is approximately 350 t CH4 (~7.35 Gg CO2 eq.) higher than that reported for 2012 in the 2014 submission.

(2) Missing estimate of accidental release under other leakage

Switzerland reports major accidents and isolated events under other leakage. The Party reassessed its estimates of fugitive emissions in 2013 based on a recent study by QUANTIS (2014). During the review, Switzerland provided the ERT with a copy of this study. The QUANTIS report indicates that two accidents occurred, one in 2010 and another in 2011. Switzerland estimated and reported CH4 emissions associated with the accident in 2010 but did not report the emissions associated with the accident in 2011.

During the review, Switzerland informed the ERT that a preliminary version of the QUANTIS study was used in preparation of the 2014 inventory submission and that in this preliminary version, reporting of these accidents was incomplete. As a consequence, the event of 2011, implying a release of 500t CH4 (10.5 Gg CO2 eq.) was not considered.

The ERT considers that not reporting the amount of CH4 emitted during the accidental release in 2011 constitutes a potential underestimation.

During the review, Switzerland indicated that these two errors were detected too late to be taken into account for the 2014 submission.

Recommendation by ERT:

The ERT recommends that Switzerland submit revised estimates of fugitive emissions, including the detected missing estimates, for the whole time series.

Response / Information by Party:

The final results from the Quantis study are taken into account, resulting in the following recalculations in sector 1B2b. The revision affects CH4 and CO2 emissions (CO2 contained in the natural gas). However, the emissions of CH4 are of much larger importance in absolute values.

		1990	2008	2009	2010	2011	2012
April 2014	Gg CO2	0.22	0.15	0.14	0.15	0.14	0.14
	Gg CH4	12.39	8.48	8.20	8.49	7.89	7.88
Revised	Gg CO2	0.22	0.16	0.15	0.16	0.15	0.14
	Gg CH4	12.62	8.85	8.63	9.03	8.77	8.25
Difference	Gg CO2	0.004	0.01	0.01	0.01	0.02	0.01
	Gg CH4	0.23	0.37	0.43	0.54	0.88	0.37
Total difference	**Gg CO2eq**	4.9	7.8	9.1	11.4	18.5	7.7

Potential problem unsolved? Rationale:

Resolved. Switzerland recalculated the emissions taking into consideration the most recent results from the Quantis study, which were not available early enough to be included in the 2014 submission.

Overview of inventory potential problems identified for 2012

Annex A sources

2014 GHG inventory review

Switzerland

Abbreviations:

GPG: IPCC good practice guidance

AD: activity data, EF: emission factor, IEF: implied emission factor

KC: key category, ERT: Expert Review Team

Sector, category, sub-category (with code)	**Gas**	**KC / non-KC**	**Identified inventory problem in terms of:**		
			Missing estimate	**Estimate provided but not in line with GPG**	**Estimate provided but lack of transparency**
6. Waste 6.A Solid waste disposal on land	CH_4,	**KC, level, trend**		X	

Description of problem identified:

Switzerland estimated CH4 emissions from solid waste disposal using the IPCC first order decay method. CH4 emissions are calculated according to the following equation:

CH4 emissions = CH4 generated*(1-oxidation factor) – CH4 recovered +CH4 from Open burning

Where;

CH4 recovered = CH4 generated *CH4 flared fraction+ CH4 used in co-generation unit

For CH4 recovered, Switzerland reported CH4 flared and CH4 used in co-generation units in its submission.

During the review week, in response to questions raised by the ERT, Switzerland provided a detailed explanation to yield amount of CH4 recovered as below;

“The amount of CH4 used in co-generation stems from the Siwss renewable energy statistics (SFOE 2014a). Due to the fact that no reliable data for the amount of CH4 flared exists, this value is assumed to be 10% of the total amount of CH4 occurring from waste disposal sites. FOEN experts for waste disposal sites believe that this share is probably underestimating the actual amount that is flared.”

However, Switzerland could not provide any evidence to support its statement of “share (10% of the total amount of CH4) is probably underestimating the actual amount that is flared.”

The IPCC good practice guidance, Chapter 5, page 10, states that “Reporting based on metering of all gas recovered for energy utilisation and flaring is consistent with good practice. The use of undocumented estimates of landfill gas recovery potential is not appropriate, as such estimates tend to overestimate the amount of recovery.”

The ERT considers that the amount of CH4 flared reported by Switzerland is not metered data, but undocumented estimates of landfill gas recovery potential. Hence the ERT concludes the methodology is not in line with IPCC good practice guidance.

Recommendation by ERT:

The ERT recommends that Switzerland provide references documenting the amount of recovered CH4 that is flared.

If such references are available, the ERT recommends that the Party report the amount of CH4 recovered by flaring in accordance with those references. Otherwise, the ERT recommends that the Party estimate CH4 emissions from the solid waste disposal on land considering the amount of CH4 flared to be zero (the default value in the good practice guidance), for the entire time series, and submit the revised CRF tables.

Response / Information by Party:

As announced during the review, a study will be performed during the next months to get a more reliable estimate of the amount of gas flared. Because these results will not be available earlier than Nov. 2014, the amount flared has been set to zero. This results in the recalculation of the CH4 emissions in sector 6A as follows:

		1990	2008	2009	2010	2011	2012
April 2014	Gg CH4	32.77	11.15	10.09	9.43	8.47	7.54
Revised	Gg CH4	36.94	12.58	11.38	10.58	9.51	8.47
Difference	Gg CH4	4.17	1.44	1.29	1.16	1.04	0.93
Total difference	**Gg CO2eq**	**87.6**	**30.2**	**27.1**	**24.3**	**21.8**	**19.6**

Potential problem unsolved? Rationale:

Resolved. Switzerland recalculated the emissions in accordance with the recommendation by the ERT, estimating the amount of CH4 flared to be zero (the default value in the good practice guidance).

Annexes

Annex 1: Key Category Analysis (KCA)

A1.1 Methodology

The key category analysis is performed according to the IPCC Good Practice Guidance (IPCC 2006, chapter 4): An Approach 1 level and trend assessment is applied with the proposed threshold of 95%. An Approach 2 key category analysis has also been carried out for this submission with the proposed threshold of 90% of the sum of all level assessments weighted with their relative source uncertainty. All main source categories have been disaggregated into sub-sources (e.g. 2A, 2B, 2C etc.) and gases (CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6).

A1.2 Information on the level of disaggregation

For some important sources, an even more detailed level of disaggregation has been used in order to clearly identify and isolate the most important sources. Note that for each KCA category mentioned below a specific assessment according to both fuel type and GHG has been carried out.

This is the case for the important source category 1A Energy Fuel Combustion sources, where the source categories have been disaggregated further to the level of sub-categories as for example 1A1 Fuel Combustion – Energy Industries, 1A2 Fuel Combustion – Manufacturing Industries, etc. Even further disaggregation has been realized for the source category Transport (1A3) and Other Sectors (1A4):

The source Transport (1A3) has been further split into Civil Aviation (1A3a), Road Transportation (1A3b), Railways (1A3c), and Navigation (1A3d).

A more detailed disaggregation has also been carried out for Other Sectors (1A4), which has been split into Commercial/Institutional (1A4a), Residential (1A4b) and Agriculture/Forestry (1A4c).

The categories Mineral industry (2A), Metal industry (2C), Product uses as substitutes for ODS (2F) and Other product manufacture and use (2G) are disaggregated into their source categories (e.g. 2A1, 2A2, etc.).

Agricultural Soils (3D) is split into its source categories 3D1 to 3D4.

Uncertainty data have been taken from the uncertainty analysis, where the disaggregation of source and sink categories is in accordance with the key category analysis.

A summary of the results of the KCA analyses is displayed in Table A-1.

A1.3 KCA Approach 1 2013 including LULUCF categories

Results of Key Category Analysis Approach 1 – Level and Trend

Table A – 1 Key category analysis Approach 1 2013 (including LULUCF), overview

Approach 1 Key Category Analysis - Level Assessment for the year 2013 with all categories shown (ordered by category code)								
No.	IPCC source categories and fuels if applicable				GHG	Year 1990 estimate [Gg CO2 eq]	Year 2013 estimate [Gg CO2 eq]	Result KCA assessment
1	1A1	A. Fuel combustion activities	1. Energy industries	Biomass	CH4	0.45	0.41	
2	1A1	A. Fuel combustion activities	1. Energy industries	Gaseous Fuels	CH4	0.74	1.25	
3	1A1	A. Fuel combustion activities	1. Energy industries	Liquid Fuels	CH4	0.59	0.82	
4	1A1	A. Fuel combustion activities	1. Energy industries	Solid Fuels	CH4	0.12	0.00	
5	1A1	A. Fuel combustion activities	1. Energy industries	Gaseous Fuels	CO2	276.38	468.80	L1, T1
6	1A1	A. Fuel combustion activities	1. Energy industries	Liquid Fuels	CO2	693.69	945.83	L1, T1
7	1A1	A. Fuel combustion activities	1. Energy industries	Other Fuels	CO2	1491.55	2228.12	L1, L2, T1, T2
8	1A1	A. Fuel combustion activities	1. Energy industries	Solid Fuels	CO2	44.84	0.00	
9	1A1	A. Fuel combustion activities	1. Energy industries	Biomass	N2O	22.58	16.48	
10	1A1	A. Fuel combustion activities	1. Energy industries	Gaseous Fuels	N2O	0.15	0.25	
11	1A1	A. Fuel combustion activities	1. Energy industries	Liquid Fuels	N2O	2.07	2.65	
12	1A1	A. Fuel combustion activities	1. Energy industries	Other Fuels	N2O	24.33	13.05	
13	1A1	A. Fuel combustion activities	1. Energy industries	Solid Fuels	N2O	0.23	0.00	
14	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Biomass	CH4	4.18	2.23	
15	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Gaseous Fuels	CH4	3.13	5.99	
16	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Liquid Fuels	CH4	3.43	1.51	
17	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Other Fuels	CH4	0.00	0.00	
18	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Solid Fuels	CH4	0.34	0.19	
19	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Gaseous Fuels	CO2	1057.12	2255.42	L1, L2, T1, T2
20	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Liquid Fuels	CO2	3875.05	2274.91	L1, T1
21	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Other Fuels	CO2	134.16	312.93	L1, L2, T1, T2
22	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Solid Fuels	CO2	1155.82	490.74	L1, L2, T1, T2
23	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Biomass	N2O	3.91	13.26	
24	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Gaseous Fuels	N2O	0.56	1.18	
25	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Liquid Fuels	N2O	14.12	10.58	
26	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Other Fuels	N2O	2.19	5.48	
27	1A2	A. Fuel combustion activities	2. Manufacturing industries and construction	Solid Fuels	N2O	5.94	2.50	
28	1A3a	A. Fuel combustion activities	3. Transport; Domestic aviation		CH4	0.29	0.26	
29	1A3a	A. Fuel combustion activities	3. Transport; Domestic aviation		CO2	252.55	132.29	T1
30	1A3a	A. Fuel combustion activities	3. Transport; Domestic aviation		N2O	2.39	1.26	
31	1A3b	A. Fuel combustion activities	3. Transport; Road transportation	Biomass	CH4	0.00	-0.04	
32	1A3b	A. Fuel combustion activities	3. Transport; Road transportation	Diesel	CH4	1.64	0.66	
33	1A3b	A. Fuel combustion activities	3. Transport; Road transportation	Gaseous Fuels	CH4	0.00	0.08	
34	1A3b	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	CH4	116.05	21.00	T1, T2
35	1A3b	A. Fuel combustion activities	3. Transport; Road transportation	Diesel	CO2	2587.68	7137.84	L1, T1
36	1A3b	A. Fuel combustion activities	3. Transport; Road transportation	Gaseous Fuels	CO2	0.00	62.60	
37	1A3b	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	CO2	11335.27	8608.76	L1, T1
38	1A3b	A. Fuel combustion activities	3. Transport; Road transportation	Biomass	N2O	0.00	0.82	
39	1A3b	A. Fuel combustion activities	3. Transport; Road transportation	Diesel	N2O	5.52	69.60	
40	1A3b	A. Fuel combustion activities	3. Transport; Road transportation	Gaseous Fuels	N2O	0.00	1.98	
41	1A3b	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	N2O	136.89	22.82	T1, T2
42	1A3c	A. Fuel combustion activities	3. Transport; Railways	Liquid Fuels	CH4	0.01	0.01	
43	1A3c	A. Fuel combustion activities	3. Transport; Railways	Liquid Fuels	CO2	28.69	39.61	
44	1A3c	A. Fuel combustion activities	3. Transport; Railways	Liquid Fuels	N2O	0.37	0.50	
45	1A3d	A. Fuel combustion activities	3. Transport; Domestic navigation	Liquid Fuels	CH4	0.71	0.66	
46	1A3d	A. Fuel combustion activities	3. Transport; Domestic navigation	Liquid Fuels	CO2	111.93	120.03	
47	1A3d	A. Fuel combustion activities	3. Transport; Domestic navigation	Liquid Fuels	N2O	1.21	1.32	
48	1A3e	A. Fuel combustion activities	3. Transport; Other transportation	Gaseous Fuels	CH4	0.07	0.03	
49	1A3e	A. Fuel combustion activities	3. Transport; Other transportation	Gaseous Fuels	CO2	31.42	23.12	
50	1A3e	A. Fuel combustion activities	3. Transport; Other transportation	Gaseous Fuels	N2O	0.02	0.01	
51	1A4a	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Biomass	CH4	9.23	4.05	
52	1A4a	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Gaseous Fuels	CH4	2.86	4.77	
53	1A4a	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Liquid Fuels	CH4	3.41	1.73	
54	1A4a	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Gaseous Fuels	CO2	984.01	1572.39	L1, L2, T1, T2
55	1A4a	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Liquid Fuels	CO2	4260.88	3286.01	L1, T1
56	1A4a	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Biomass	N2O	3.50	8.59	
57	1A4a	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Gaseous Fuels	N2O	0.52	0.83	
58	1A4a	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Liquid Fuels	N2O	10.41	8.10	
59	1A4b	A. Fuel combustion activities	4. Other sectors; Residential	Biomass	CH4	109.96	32.07	T1
60	1A4b	A. Fuel combustion activities	4. Other sectors; Residential	Gaseous Fuels	CH4	3.94	7.87	
61	1A4b	A. Fuel combustion activities	4. Other sectors; Residential	Liquid Fuels	CH4	7.04	2.68	
62	1A4b	A. Fuel combustion activities	4. Other sectors; Residential	Solid Fuels	CH4	4.73	3.00	
63	1A4b	A. Fuel combustion activities	4. Other sectors; Residential	Gaseous Fuels	CO2	1458.04	2892.76	L1, L2, T1, T2
64	1A4b	A. Fuel combustion activities	4. Other sectors; Residential	Liquid Fuels	CO2	10099.18	7334.47	L1, T1
65	1A4b	A. Fuel combustion activities	4. Other sectors; Residential	Solid Fuels	CO2	58.40	37.08	
66	1A4b	A. Fuel combustion activities	4. Other sectors; Residential	Biomass	N2O	26.14	24.12	
67	1A4b	A. Fuel combustion activities	4. Other sectors; Residential	Gaseous Fuels	N2O	0.77	1.53	
68	1A4b	A. Fuel combustion activities	4. Other sectors; Residential	Liquid Fuels	N2O	24.57	17.87	
69	1A4b	A. Fuel combustion activities	4. Other sectors; Residential	Solid Fuels	N2O	0.30	0.19	
70	1A4c	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Biomass	CH4	1.97	0.41	
71	1A4c	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Gaseous Fuels	CH4	0.11	0.02	
72	1A4c	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Liquid Fuels	CH4	1.93	1.69	
73	1A4c	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Gaseous Fuels	CO2	41.45	5.96	
74	1A4c	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Liquid Fuels	CO2	547.34	513.86	L1
75	1A4c	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Biomass	N2O	0.51	0.79	
76	1A4c	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Gaseous Fuels	N2O	0.02	0.00	
77	1A4c	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Liquid Fuels	N2O	4.76	5.28	
78	1A5	A. Fuel combustion activities	5. Other	Liquid Fuels	CH4	0.19	0.14	
79	1A5	A. Fuel combustion activities	5. Other	Liquid Fuels	CO2	203.58	115.64	T1
80	1A5	A. Fuel combustion activities	5. Other	Liquid Fuels	N2O	1.93	1.10	
81	1B2	B. Fugitive emissions from fuels	2. Oil and natural gas and other emissions from ener		CH4	319.73	212.08	L1, T1, T2
82	1B2	B. Fugitive emissions from fuels	2. Oil and natural gas and other emissions from ener		CO2	84.62	53.90	
83	1B2	B. Fugitive emissions from fuels	2. Oil and natural gas and other emissions from ener		N2O	0.60	0.94	

Table A – 1 Continued Key category analysis Approach 1 2013 (including LULUCF),overview

Approach 1 Key Category Analysis - Level Assessment for the year 2013 with all categories shown (ordered by category code)							
No.	IPCC source categories and fuels if applicable			GHG	Year 1990 estimate [Gg CO2 eq]	Year 2013 estimate [Gg CO2 eq]	Result KCA assessment
84	2A1	A. Mineral industry	1. Cement production	CO2	2524.45	1811.87	L1, T1
85	2A2	A. Mineral industry	2. Lime production	CO2	53.35	51.06	
86	2A3	A. Mineral industry	3. Glass production	CO2	15.25	6.49	
87	2A4	A. Mineral industry	4. Other process uses of carbonates	CO2	156.15	85.84	T1, T2
88	2B	B. Chemical industry		CH4	1.83	2.12	
89	2B	B. Chemical industry		CO2	121.59	126.81	
90	2B	B. Chemical industry		N2O	65.49	27.11	
91	2C1	C. Metal industry	1. Iron and steel production	CO2	9.20	10.34	
92	2C3	C. Metal industry	3. Aluminium production	CO2	139.26	0.00	T1
93	2C3	C. Metal industry	3. Aluminium production	PFC	116.46	0.00	T1
94	2C4	C. Metal industry	4. Magnesium production	SF6	0.00	42.07	
95	2C7	C. Metal industry	7. Other	CO2	1.65	1.30	
96	2D	D. Non-energy products from fuels and so		CO2	72.79	100.78	
97	2E1	E. Electronics industry	1. Integrated circuit or semiconductor	PFC	0.00	5.02	
98	2E1	E. Electronics industry	1. Integrated circuit or semiconductor	SF6	0.00	12.17	
99	2E3	E. Electronics industry	3. Photovoltaics	NF3	0.00	0.10	
100	2E4	F. Product uses as substitutes for ODS	4. Heat transfer fluid	PFC	0.00	0.15	
101	2F1	F. Product uses as substitutes for ODS	1. Refrigeration and air conditioning	HFC	0.02	1396.88	L1, L2, T1, T2
102	2F1	F. Product uses as substitutes for ODS	1. Refrigeration and air conditioning	PFC	0.05	8.22	
103	2F2	F. Product uses as substitutes for ODS	2. Foam blowing agents	HFC	0.00	32.94	
104	2F4	F. Product uses as substitutes for ODS	4. Aerosols	HFC	0.00	22.00	
105	2F5	F. Product uses as substitutes for ODS	5. Solvents	HFC	0.00	1.92	
106	2G	G. Other product manufacture and use		CO2	0.04	0.10	
107	2G	G. Other product manufacture and use		HFC	0.00	66.15	T1
108	2G	G. Other product manufacture and use		PFC	0.00	38.61	
109	2G	G. Other product manufacture and use		SF6	137.01	198.21	L1
110	2G	G. Other product manufacture and use		N2O	105.87	43.39	T2
111	2H	H. Other		CO2	1.04	0.89	
112	3A	A. Enteric fermentation		CH4	3511.54	3238.97	L1, L2, T1, T2
113	3B	B. Manure management		CH4	908.04	759.58	L1, L2, T1, T2
114	3B1-3B4	B. Manure management	1. Cattle, 2. Sheep, 3. Swine, 4. Other livestock	N2O	105.64	85.40	
115	3B5	B. Manure management	5. Indirect N2O emissions	N2O	242.32	280.61	L1, L2, T2
116	3Da	D. Agricultural soils; Direct emissions from		N2O	1238.00	1061.64	L1, L2, T1, T2
117	3Db	D. Agricultural soils; Indirect emissions fro		N2O	658.05	481.26	L1, L2, T1, T2
118	3G	G. Liming		CO2	22.57	32.58	
119	3H	H. Urea application		CO2	26.71	9.45	
120	4 II	Drainage, rewetting and other manageme		CH4	10.75	10.75	
121	4 II	Drainage, rewetting and other manageme		N2O	6.91	7.01	
122	4 III	N mineralization		N2O	61.10	53.05	
123	4 IV	Indirect emissions		N2O	13.75	11.94	
124	4 V	Biomass burning		CH4	25.36	0.54	
125	4 V	Biomass burning		CO2	25.36	0.55	
126	4 V	Biomass burning		N2O	4.77	0.09	
127	4A1	A. Forest land	1. Forest land remaining forest land	CO2	-2342.87	-2258.41	L1, L2
128	4A2	A. Forest land	2. Land converted to forest land	CO2	-621.02	-425.44	L1, L2, T1, T2
129	4B1	B. Cropland	1. Cropland remaining cropland	CO2	364.73	842.28	L1, L2, T1, T2
130	4B2	B. Cropland	2. Land converted to cropland	CO2	47.60	24.16	
131	4C1	C. Grassland	1. Grassland remaining grassland	CO2	86.70	121.07	L2, T2
132	4C2	C. Grassland	2. Land converted to grassland	CO2	49.75	159.18	L2, T1, T2
133	4D1	D. Wetlands	1. Wetlands remaining wetlands	CO2	3.14	55.61	T2
134	4D2	D. Wetlands	2. Land converted to wetlands	CO2	20.64	29.57	
135	4E1	E. Settlements	1. Settlements remaining settlements	CO2	20.05	57.19	
136	4E2	E. Settlements	2. Land converted to settlements	CO2	394.80	307.51	L1, L2, T1, T2
137	4F2	F. Other land	2. Land converted to other land	CO2	93.93	115.18	
138	4G	G. Harvested wood products		CO2	-1218.45	-147.91	T1, T2
139	5A	A. Solid waste disposal		CH4	923.53	191.70	L1, L2, T1, T2
140	5A	A. Solid waste disposal		CO2	9.04	0.00	
141	5B	B. Biological treatment of solid waste		CH4	81.83	468.63	L1, L2, T1, T2
142	5B	B. Biological treatment of solid waste		N2O	5.66	25.65	
143	5C	C. Incineration and open burning of waste		CH4	13.79	7.17	
144	5C	C. Incineration and open burning of waste		CO2	53.73	9.82	
145	5C	C. Incineration and open burning of waste		N2O	18.32	28.11	
146	5D	D. Wastewater treatment and discharge		CH4	130.92	173.34	L1, L2
147	5D	D. Wastewater treatment and discharge		N2O	117.87	148.54	
148	6			CH4	0.66	0.68	
149	6			CO2	10.96	12.92	
150	6			N2O	0.60	0.60	

Annex 2: Assessment of Uncertainty

A2.1 Detailed Results of Approach 1 Uncertainty Analysis

The table on the next pages shows the detailed results of Approach 1 Uncertainty analysis. The structure of the table is identical to Table 3.2 of IPCC 2006 Guidelines (IPCC 2006). For explanations to the columns see pp. 3.30-3.31 in vol. 1 IPCC (2006).

Table A – 2 Results of Approach 1 uncertainty analysis. (Table 3.2 of IPCC 2006 Guidelines)

IPCC Source category					Gas	Base year emissions or removals	Year 2013 emissions or removals	AD uncertainty	EF uncertainty	Combined uncertainty	Contribution to variance by Category in 2013	Type A sensitivity	Type B sensitivity	Uncertainty in trend in nat. emissions introduced by EF uncertainty	Uncertainty in trend in nat. emissions introduced by AD uncertainty	Uncertainty introduced into the trend in total national emissions
						Gg CO2 eq	Gg CO2 eq	%	%	%	-	%	%	%	%	-
1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Biomass	CH4	0.45	0.41	10.0	28.3	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Gaseous F.	CH4	0.74	1.25	5.0	29.6	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Liquid F.	CH4	0.59	0.82	1.0	30.0	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Solid F.	CH4	0.12	-	5.0	29.6	30.0	-	0.0000	-	0.00	-	0.00
				Gaseous F.	CO2	276.38	468.80	5.0	4.6	6.8	0.004	0.0037	0.0091	0.02	0.06	0.00
				Liquid F.	CO2	693.69	945.83	1.0	0.5	1.1	0.000	0.0047	0.0184	0.00	0.03	0.00
				Other F.	CO2	1'491.55	2'228.12	10.0	30.0	31.6	1.870	0.0139	0.0432	0.42	0.61	0.55
				Solid F.	CO2	44.84	-	5.0	5.0	7.1	-	0.0009	-	0.00	-	0.00
				Biomass	N2O	22.58	16.48	10.0	79.4	80.0	0.001	0.0001	0.0003	0.01	0.00	0.00
				Gaseous F.	N2O	0.15	0.25	5.0	79.8	80.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Liquid F.	N2O	2.07	2.65	1.0	80.0	80.0	0.000	0.0000	0.0001	0.00	0.00	0.00
				Other F.	N2O	24.33	13.05	10.0	79.4	80.0	0.000	0.0002	0.0003	0.02	0.00	0.00
				Solid F.	N2O	0.23	-	5.0	79.8	80.0	-	0.0000	-	0.00	-	0.00
1A2			2. Manufacturing industries and construction	Biomass	CH4	4.18	2.23	10.0	28.3	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Gaseous F.	CH4	3.13	5.99	5.0	29.6	30.0	0.000	0.0001	0.0001	0.00	0.00	0.00
				Liquid F.	CH4	3.43	1.51	1.0	30.0	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Other F.	CH4	-	-	10.0	28.3	30.0	-	-	-	-	-	-
				Solid F.	CH4	0.34	0.19	5.0	29.6	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Gaseous F.	CO2	1'057.12	2'255.42	5.0	4.6	6.8	0.088	0.0233	0.0438	0.11	0.31	0.11
				Liquid F.	CO2	3'875.05	2'274.91	1.0	0.5	1.1	0.002	0.0335	0.0442	0.02	0.06	0.00
				Other F.	CO2	134.16	312.93	10.0	30.0	31.6	0.037	0.0035	0.0061	0.10	0.09	0.02
				Solid F.	CO2	1'155.82	490.74	5.0	29.6	30.0	0.082	0.0137	0.0095	0.41	0.07	0.17
				Biomass	N2O	3.91	13.26	10.0	79.4	80.0	0.000	0.0002	0.0003	0.01	0.00	0.00
				Gaseous F.	N2O	0.56	1.18	5.0	79.8	80.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Liquid F.	N2O	14.12	10.58	1.0	80.0	80.0	0.000	0.0001	0.0002	0.01	0.00	0.00
				Other F.	N2O	2.19	5.48	10.0	79.4	80.0	0.000	0.0001	0.0001	0.01	0.00	0.00
				Solid F.	N2O	5.94	2.50	5.0	79.8	80.0	0.000	0.0001	0.0000	0.01	0.00	0.00
1A3a			3. Transport; Domestic aviation		CH4	0.29	0.26	1.0	60.0	60.0	0.000	0.0000	0.0000	0.00	0.00	0.00
					CO2	252.55	132.29	1.0	1.2	1.5	0.000	0.0025	0.0026	0.00	0.00	0.00
					N2O	2.39	1.26	1.0	150.0	150.0	0.000	0.0000	0.0000	0.00	0.00	0.00

IPCC Source category					Gas	Base year emissions or removals	Year 2013 emissions or removals	AD uncertainty	EF uncertainty	Combined uncertainty	Contribution to variance by Category in 2013	Type A sensitivity	Type B sensitivity	Uncertainty in trend in nat. emissions introduced by EF uncertainty	Uncertainty in trend in nat. emissions introduced by AD uncertainty	Uncertainty introduced into the trend in total national emissions
						Gg CO2 eq	Gg CO2 eq	%	%	%	-	%	%	%	%	-
1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Biomass	CH4	-	-0.04	1.0	60.0	60.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A3b				Diesel	CH4	1.64	0.66	1.0	20.0	20.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A3b				Gaseous F.	CH4	-	0.08	5.0	29.6	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A3b				Gasoline	CH4	116.05	21.00	1.0	37.0	37.0	0.000	0.0019	0.0004	0.07	0.00	0.01
1A3b				Diesel	CO2	2'587.68	7'137.84	1.0	0.5	1.1	0.023	0.0891	0.1385	0.04	0.20	0.04
1A3b				Gaseous F.	CO2	-	62.60	5.0	4.6	6.8	0.000	0.0012	0.0012	0.01	0.01	0.00
1A3b				Gasoline	CO2	11'335.27	8'608.76	1.0	1.4	1.7	0.079	0.0592	0.1671	0.08	0.24	0.06
1A3b				Biomass	N2O	-	0.82	1.0	150.0	150.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A3b				Diesel	N2O	5.52	69.60	1.0	22.0	22.0	0.001	0.0013	0.0014	0.03	0.00	0.00
1A3b				Gaseous F.	N2O	-	1.98	5.0	79.8	80.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A3b				Gasoline	N2O	136.89	22.82	1.0	50.0	50.0	0.000	0.0023	0.0004	0.12	0.00	0.01
1A3c			3. Transport; Railways	Liquid F.	CH4	0.01	0.01	1.0	30.0	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A3c				Liquid F.	CO2	28.69	39.61	1.0	0.5	1.1	0.000	0.0002	0.0008	0.00	0.00	0.00
1A3c				Liquid F.	N2O	0.37	0.50	1.0	150.0	150.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A3d			3. Transport; Domestic navigation	Liquid F.	CH4	0.71	0.66	1.0	30.0	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A3d				Liquid F.	CO2	111.93	120.03	1.0	0.5	1.1	0.000	0.0001	0.0023	0.00	0.00	0.00
1A3d				Liquid F.	N2O	1.21	1.32	1.0	150.0	150.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A3e			3. Transport; Other transportation	Gaseous F.	CH4	0.07	0.03	5.0	29.6	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A3e				Gaseous F.	CO2	31.42	23.12	5.0	8.7	10.0	0.000	0.0002	0.0004	0.00	0.00	0.00
1A3e				Gaseous F.	N2O	0.02	0.01	5.0	79.8	80.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A4a			4. Other sectors; Commercial/institutional	Biomass	CH4	9.23	4.05	10.0	28.3	30.0	0.000	0.0001	0.0001	0.00	0.00	0.00
1A4a				Gaseous F.	CH4	2.86	4.77	5.0	29.6	30.0	0.000	0.0000	0.0001	0.00	0.00	0.00
1A4a				Liquid F.	CH4	3.41	1.73	1.0	30.0	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A4a				Gaseous F.	CO2	984.01	1'572.39	5.0	4.6	6.8	0.043	0.0112	0.0305	0.05	0.22	0.05
1A4a				Liquid F.	CO2	4'260.88	3'286.01	1.0	0.5	1.1	0.005	0.0213	0.0638	0.01	0.09	0.01
1A4a				Biomass	N2O	3.50	8.59	10.0	79.4	80.0	0.000	0.0001	0.0002	0.01	0.00	0.00
1A4a				Gaseous F.	N2O	0.52	0.83	5.0	79.8	80.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A4a				Liquid F.	N2O	10.41	8.10	1.0	80.0	80.0	0.000	0.0001	0.0002	0.00	0.00	0.00
1A4b			4. Other sectors; Residential	Biomass	CH4	109.96	32.07	10.0	28.3	30.0	0.000	0.0016	0.0006	0.05	0.01	0.00
1A4b				Gaseous F.	CH4	3.94	7.87	5.0	29.6	30.0	0.000	0.0001	0.0002	0.00	0.00	0.00
1A4b			4. Other sectors; Residential	Liquid F.	CH4	7.04	2.68	1.0	30.0	30.0	0.000	0.0001	0.0001	0.00	0.00	0.00
1A4b				Solid F.	CH4	4.73	3.00	5.0	29.6	30.0	0.000	0.0000	0.0001	0.00	0.00	0.00
1A4b				Gaseous F.	CO2	1'458.04	2'892.76	5.0	4.6	6.8	0.145	0.0278	0.0561	0.13	0.40	0.17
1A4b				Liquid F.	CO2	10'099.18	7'334.47	1.0	0.5	1.1	0.025	0.0594	0.1423	0.03	0.20	0.04
1A4b				Solid F.	CO2	58.40	37.08	5.0	5.0	7.1	0.000	0.0005	0.0007	0.00	0.01	0.00
1A4b				Biomass	N2O	26.14	24.12	10.0	79.4	80.0	0.001	0.0001	0.0005	0.00	0.01	0.00
1A4b				Gaseous F.	N2O	0.77	1.53	5.0	79.8	80.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A4b				Liquid F.	N2O	24.57	17.87	1.0	80.0	80.0	0.001	0.0001	0.0003	0.01	0.00	0.00
1A4b				Solid F.	N2O	0.30	0.19	5.0	79.8	80.0	0.000	0.0000	0.0000	0.00	0.00	0.00

IPCC Source category					Gas	Base year emissions or removals	Year 2013 emissions or removals	AD uncertainty	EF uncertainty	Combined uncertainty	Contribution to variance by Category in 2013	Type A sensitivity	Type B sensitivity	Uncertainty in trend in nat. emissions introduced by EF uncertainty	Uncertainty in trend in nat. emissions introduced by AD uncertainty	Uncertainty introduced into the trend in total national emissions
						Gg CO2 eq	Gg CO2 eq	%	%	%	-	%	%	%	%	-
1A4c	1. Energy	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Biomass	CH4	1.97	0.41	10.0	28.3	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A4c				Gaseous F.	CH4	0.11	0.02	5.0	29.6	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A4c				Liquid F.	CH4	1.93	1.69	1.0	30.0	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A4c				Gaseous F.	CO2	41.45	5.96	5.0	4.6	6.8	0.000	0.0007	0.0001	0.00	0.00	0.00
1A4c				Liquid F.	CO2	547.34	513.86	1.0	0.5	1.1	0.000	0.0009	0.0100	0.00	0.01	0.00
1A4c				Biomass	N2O	0.51	0.79	10.0	79.4	80.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A4c				Gaseous F.	N2O	0.02	0.00	5.0	79.8	80.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A4c				Liquid F.	N2O	4.76	5.28	1.0	80.0	80.0	0.000	0.0000	0.0001	0.00	0.00	0.00
1A5			5. Other	Liquid F.	CH4	0.19	0.14	1.0	30.0	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A5				Liquid F.	CO2	203.58	115.64	1.0	0.5	1.1	0.000	0.0018	0.0022	0.00	0.00	0.00
1A5				Liquid F.	N2O	1.93	1.10	1.0	150.0	150.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1B2		B. Fugitive emissions from fuels	2. Oil and natural gas and other emissions from energy production		CH4	319.73	212.08	5.0	29.6	30.0	0.015	0.0023	0.0041	0.07	0.03	0.01
1B2					CO2	84.62	53.90	5.0	8.7	10.0	0.000	0.0006	0.0010	0.01	0.01	0.00
1B2					N2O	0.60	0.94	5.0	79.8	80.0	0.000	0.0000	0.0000	0.00	0.00	0.00
2A1	2. Industrial processes and product use	A. Mineral industry	1. Cement production		CO2	2'524.45	1'811.87	2.0	2.0	2.8	0.010	0.0153	0.0352	0.03	0.10	0.01
2A2			2. Lime production		CO2	53.35	51.06	1.4	1.4	2.0	0.000	0.0001	0.0010	0.00	0.00	0.00
2A3			3. Glass production		CO2	15.25	6.49	1.4	1.4	2.0	0.000	0.0002	0.0001	0.00	0.00	0.00
2A4			4. Other process uses of carbonates		CO2	156.15	85.84	1.4	51.0	51.0	0.007	0.0015	0.0017	0.07	0.00	0.01
2B		B. Chemical industry			CH4	1.83	2.12	7.1	29.2	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
2B					CO2	121.59	126.81	7.1	7.1	10.0	0.001	0.0000	0.0025	0.00	0.02	0.00
2B					N2O	65.49	27.11	7.1	40.4	41.0	0.000	0.0008	0.0005	0.03	0.01	0.00
2C1		C. Metal industry	1. Iron and steel production		CO2	9.20	10.34	5.0	40.0	40.3	0.000	0.0000	0.0002	0.00	0.00	0.00
2C3			3. Aluminium production		CO2	139.26	-	7.1	7.1	10.0	-	0.0028	-	0.02	-	0.00
2C3			3. Aluminium production		PFC	116.46	-	6.4	6.4	9.0	-	0.0024	-	0.02	-	0.00
2C4			4. Magnesium production		SF6	-	42.07	25.8	25.8	36.5	0.001	0.0008	0.0008	0.02	0.03	0.00
2C7			7. Other		CO2	1.65	1.30	7.1	7.1	10.0	0.000	0.0000	0.0000	0.00	0.00	0.00
2D		D. Non-energy products from fuels and solvent use			CO2	72.79	100.78	35.4	35.4	50.0	0.010	0.0005	0.0020	0.02	0.10	0.01
2E1		E. Electronics industry	1. Integrated circuit or semiconductor		PFC	-	5.02	42.9	42.9	60.6	0.000	0.0001	0.0001	0.00	0.01	0.00
2E1					SF6	-	12.17	40.3	40.3	57.1	0.000	0.0002	0.0002	0.01	0.01	0.00
2E3			3. Photovoltaics		NF3	-	0.10	65.2	65.2	92.2	0.000	0.0000	0.0000	0.00	0.00	0.00
2E4			4. Heat transfer fluid		PFC	-	0.15	42.9	42.9	60.6	0.000	0.0000	0.0000	0.00	0.00	0.00
2F1		F. Product uses as substitutes for ODS	1. Refrigeration and air conditioning		HFC	0.02	1'396.88	11.7	11.7	16.6	0.202	0.0277	0.0271	0.33	0.45	0.31
2F1					PFC	0.05	8.22	11.7	11.7	16.6	0.000	0.0002	0.0002	0.00	0.00	0.00
2F2			2. Foam blowing agents		HFC	-	32.94	10.4	10.4	14.7	0.000	0.0007	0.0006	0.01	0.01	0.00
2F4			4. Aerosols		HFC	-	22.00	28.7	28.7	40.6	0.000	0.0004	0.0004	0.01	0.02	0.00
2F5			5. Solvents		HFC	-	1.92	38.9	38.9	55.0	0.000	0.0000	0.0000	0.00	0.00	0.00

IPCC Source category			Gas	Base year emissions or removals	Year 2013 emissions or removals	AD uncertainty	EF uncertainty	Combined uncertainty	Contribution to variance by Category in 2013	Type A sensitivity	Type B sensitivity	Uncertainty in trend in nat. emissions introduced by EF uncertainty	Uncertainty in trend in nat. emissions introduced by AD uncertainty	Uncertainty introduced into the trend in total national emissions
				Gg CO2 eq	Gg CO2 eq	%	%	%	-	%	%	%	%	-
2G	2. Ind. Processes	G. Other product manufacture and use	CO2	0.04	0.10	35.4	35.4	50.0	0.000	0.0000	0.0000	0.00	0.00	0.00
2G	2. Ind. Processes	G. Other product manufacture and use	HFC	-	66.15	11.4	11.4	16.1	0.000	0.0013	0.0013	0.01	0.02	0.00
2G	2. Ind. Processes	G. Other product manufacture and use	PFC	-	38.61	6.4	6.4	9.1	0.000	0.0008	0.0007	0.00	0.01	0.00
2G	2. Ind. Processes	G. Other product manufacture and use	SF6	137.01	198.21	12.3	12.3	17.4	0.005	0.0012	0.0038	0.01	0.07	0.00
2G	2. Ind. Processes	G. Other product manufacture and use	N2O	105.87	43.39	35.4	71.8	80.0	0.005	0.0013	0.0008	0.09	0.04	0.01
2H	2. Ind. Processes	H. Other	CO2	1.04	0.89	7.1	7.1	10.0	0.000	0.0000	0.0000	0.00	0.00	0.00
3A	3. Agriculture	A. Enteric fermentation	CH4	3'511.54	3'238.97	6.4	16.9	18.1	1.298	0.0070	0.0629	0.12	0.57	0.34
3B	3. Agriculture	B. Manure Management -	CH4	908.04	759.58	6.4	54.0	54.4	0.643	0.0034	0.0147	0.18	0.13	0.05
3B	3. Agriculture	B. Manure Management liquid	N2O	-	10.58	32.0	75.0	81.5	0.000	0.0002	0.0002	0.02	0.01	0.00
3B	3. Agriculture	B. Manure Management solid	N2O	105.64	74.81	32.0	75.0	81.5	0.014	0.0007	0.0015	0.05	0.07	0.01
3B	3. Agriculture	B. Manure Management indirect	N2O	242.32	280.61	46.5	240.0	244.5	1.773	0.0006	0.0054	0.16	0.36	0.15
3D	3. Agriculture	D. Agricultural Soils; Direct Soil Emissions fertilizer	N2O	1'046.93	785.72	15.0	135.0	135.8	4.290	0.0057	0.0152	0.77	0.32	0.69
3D	3. Agriculture	D. Agricultural Soils; Direct Soil Emissions organic soils	N2O	69.28	66.69	29.4	137.5	140.6	0.033	0.0001	0.0013	0.01	0.05	0.00
3D	3. Agriculture	D. Agricultural Soils; Pasture, Range and Paddock Manure -	N2O	121.78	209.23	68.3	132.5	149.1	0.366	0.0017	0.0041	0.22	0.39	0.20
3D	3. Agriculture	D. Agricultural Soils; Indirect Emissions deposition	N2O	462.94	334.88	39.6	240.0	243.2	2.499	0.0028	0.0065	0.66	0.36	0.57
3D	3. Agriculture	D. Agricultural Soils; Indirect Emissions leaching and runoff	N2O	195.11	146.39	22.4	163.3	164.9	0.219	0.0011	0.0028	0.17	0.09	0.04
3G	3. Agriculture	G. Limestone -	CO2	22.57	32.58	40.0	5.0	40.3	0.001	0.0002	0.0006	0.00	0.04	0.00
3H	3. Agriculture	H. Urea application -	CO2	26.71	9.45	5.0	5.0	7.1	0.000	0.0004	0.0002	0.00	0.00	0.00
5A	5. Waste	A. Solid waste disposal	CH4	923.53	191.70	10.0	50.0	51.0	0.036	0.0150	0.0037	0.75	0.05	0.56
5A	5. Waste	A. Solid waste disposal	CO2	9.04	-	10.0	25.0	26.9	-	0.0002	-	0.00	-	0.00
5B	5. Waste	B. Biological treatment of solid waste	CH4	81.83	468.63	10.0	40.0	41.2	0.141	0.0076	0.0091	0.31	0.13	0.11
5B	5. Waste	B. Biological treatment of solid waste	N2O	5.66	25.65	10.0	79.4	80.0	0.002	0.0004	0.0005	0.03	0.01	0.00
5C	5. Waste	C. Incineration and open burning of waste	CH4	13.79	7.17	10.0	10.0	14.1	0.000	0.0001	0.0001	0.00	0.00	0.00
5C	5. Waste	C. Incineration and open burning of waste	CO2	53.73	9.82	10.0	40.0	41.2	0.000	0.0009	0.0002	0.04	0.00	0.00
5C	5. Waste	C. Incineration and open burning of waste	N2O	18.32	28.11	10.0	10.0	14.1	0.000	0.0002	0.0005	0.00	0.01	0.00
5D	5. Waste	D. Wastewater treatment and discharge	CH4	130.92	173.34	36.0	32.0	48.2	0.026	0.0008	0.0034	0.03	0.17	0.03
5D	5. Waste	D. Wastewater treatment and discharge	N2O	117.87	148.54	32.0	146.5	150.0	0.187	0.0006	0.0029	0.08	0.13	0.02
6	6. Other		CH4	0.66	0.68	2.0	60.0	60.0	0.000	0.0000	0.0000	0.00	0.00	0.00
6	6. Other		CO2	10.96	12.92	2.0	39.9	40.0	0.000	0.0000	0.0003	0.00	0.00	0.00
6	6. Other		N2O	0.60	0.60	2.0	150.0	150.0	0.000	0.0000	0.0000	0.00	0.00	0.00

Code	IPCC Source category			Gas	Base year emissions or removals	Year 2013 emissions or removals	AD uncertainty	EF uncertainty	Combined uncertainty	Contribution to variance by Category in 2013	Type A sensitivity	Type B sensitivity	Uncertainty in trend in nat. emissions introduced by EF uncertainty	Uncertainty in trend in nat. emissions introduced by AD uncertainty	Uncertainty introduced into the trend in total national emissions
					Gg CO2 eq	Gg CO2 eq	%	%	%	-	%	%	%	%	-
4 II	4. LULUCF	Drainage, rewetting and other management of organic and mineral soils		CH4	10.75	10.75	10.0	70.0	70.7	0.000	0.0000	0.0002	0.00	0.00	0.00
4 II				N2O	6.91	7.01	30.0	137.5	140.7	0.000	0.0000	0.0001	0.00	0.01	0.00
4 III		N mineralization		N2O	61.10	53.05	6.0	135.0	135.1	0.019	0.0002	0.0010	0.03	0.01	0.00
4 IV		Indirect emissions		N2O	13.75	11.94	31.8	161.5	164.6	0.001	0.0000	0.0002	0.01	0.01	0.00
4 V		Biomass burning		CH4	25.36	0.54	10.0	70.0	70.7	0.000	0.0005	0.0000	0.04	0.00	0.00
4 V				CO2	25.36	0.55	10.0	70.0	70.7	0.000	0.0005	0.0000	0.04	0.00	0.00
4 V				N2O	4.77	0.09	10.0	70.0	70.7	0.000	0.0001	0.0000	0.01	0.00	0.00
4A1		A. Forest land	1. Forest land remaining forest land	CO2	-2'342.87	-2'258.41	2.0	45.0	45.0	3.898	0.0028	0.0438	0.12	0.12	0.03
4A2			2. Land converted to forest land	CO2	-621.02	-425.44	2.0	45.0	45.0	0.138	0.0042	0.0083	0.19	0.02	0.04
4B1		B. Cropland	1. Cropland remaining cropland	CO2	364.73	842.28	5.0	87.7	87.8	2.061	0.0093	0.0163	0.82	0.12	0.68
4B2			2. Land converted to cropland	CO2	47.60	24.16	6.0	129.4	129.6	0.004	0.0005	0.0005	0.06	0.00	0.00
4C1		C. Grassland	1. Grassland remaining grassland	CO2	86.70	121.07	6.0	2'316.0	2'316.0	29.614	0.0006	0.0023	1.49	0.02	2.21
4C2			2. Land converted to grassland	CO2	49.75	159.18	6.0	72.4	72.7	0.050	0.0022	0.0031	0.16	0.03	0.02
4D1		D. Wetlands	1. Wetlands remaining wetlands	CO2	3.14	55.61	30.0	100.0	104.4	0.013	0.0010	0.0011	0.10	0.05	0.01
4D2			2. Land converted to wetlands	CO2	20.64	29.57	5.0	50.0	50.2	0.001	0.0002	0.0006	0.01	0.00	0.00
4E1		E. Settlements	1. Settlements remaining settlements	CO2	20.05	57.19	5.0	50.0	50.2	0.003	0.0007	0.0011	0.04	0.01	0.00
4E2			2. Land converted to settlements	CO2	394.80	307.51	5.0	50.0	50.2	0.090	0.0019	0.0060	0.10	0.04	0.01
4F2		F. Other land	2. Land converted to other land	CO2	93.93	115.18	4.0	50.0	50.2	0.013	0.0004	0.0022	0.02	0.01	0.00
4G		G. Harvested wood products		CO2	-1'218.45	-147.91	3.0	57.0	57.1	0.027	0.0218	0.0029	1.24	0.01	1.55
Total Uncertainty including LULUCF					**50'355**	**51'525**				**50.13**					**8.97**
Percentage uncertainty in total inventory:										**7.08**				Trend uncertainty:	**2.99**

A2.2 Detailed Description of Approach 2 Uncertainty Analysis by Monte Carlo Simulation

A2.2.1 Work steps

As a first step, the shape and extent of the probability distributions are derived for the activity data and emission factors, based on measured data, literature or expert judgement. The mean values of the probability distributions are set equal to the values of the GHG inventory. In most cases, normal distributions were assumed, for some agricultural categories, triangular distributions are applied (see below).

In a second step, correlation coefficients are chosen. Correlations may have a significant effect on the overall inventory uncertainty. The more the source categories are differentiated, the more correlations can be considered. The choice was restricted to categories with relevant amounts of uncertainty. For consistency reasons (in case of over-estimations), the software Crystal Ball adjusts a few of the correlation coefficients by an average of 0.10.

In the third step, Monte Carlo simulations are carried out to produce uncertainty results (see below). Several runs were performed to study the sensitivity to the choice of correlation strengths.

A2.2.2 Assumptions for the Probability Distributions

For almost all source and sink categories, normal distributions are chosen. The important exceptions are agricultural source categories as indicated in Table A – 3.

Table A – 3 Probability distribution assigned to activity data and emission factors (1990 and 2013) of categories that are not normally distributed. For all other categories normal probability distributions have been assigned.

Source Category			Gas	Probability distribution	
				AD	EF
3B5	B. Manure Management	indirect	N2O	triangular	triangular
3Da1/2/4/5/7	D. Agricultural Soils; Direct Soil Emissions	fertilizer	N2O	normal	triangular
3Da6	D. Agricultural Soils; Direct Soil Emissions	organic soils	N2O	normal	triangular
3Da3	D. Agricultural Soils; Pasture, Range and Paddock Manure		N2O	triangular	triangular
3Db1	D. Agricultural Soils; Indirect Emissions	deposition	N2O	triangular	triangular
3Db2	D. Agricultural Soils; Indirect Emissions	leaching and runoff	N2O	triangular	triangular

A2.2.3 Assumptions for the Correlation Coefficients

Since there are no quantitative correlations available, only the following values have been used (if any are assumed):

- “strong” positive correlations are set to r = 1.0 (like perfect correlations),
- “medium” correlations are set to r = ±0. 5.
- “weak” correlations are set to r = ±0.25.

The following assumptions are made for the level uncertainty:

- Activity data of liquid and gaseous fuels from the categories 1A2, 1A4a and 1A4b are negatively correlated (r = -0.5), since the total amount is well known but the partitioning into the different categories is less precisely known. By chosing negative correlations, overestimations in a category during the simulations are compensated by underestimations in one or more of the other categories.

- Activity data of 3A (Enteric Fermentation) and 3B (Manure Management) are positively correlated (r=0.5) since they are both based on the same livestock numbers.
- Activity data 3B liquid and 3Db Indirect N_2O emissions (3Db1 deposition and 3Db2 leaching and runoff) are medium and positively correlated.

The following assumptions are made for the trend uncertainty:

- The CO_2 emission factor of category 1A1 (Other fuels) is medium and positively correlated (r = 0.5) between 1990 and 2013.
- Activity data/emissions of the major sources (1A2: CO_2, 1A3: CO_2, 1A4: CO_2, 3A: CH_4, 3B: CH_4, 2F: HFC) are medium and positively correlated between 1990 and 2013 (r = 0.5).
- The emission factors of agricultural categories are strongly and positively correlated between 1990 and 2013.

Table A – 4 Correlation coefficients for activity data of categories 1A and 2F . “b_”: base year 1990.” t_”: 2013.

	b_AD_1A2_Gaseous Fuels_CO2 (Approach 2)	t_AD_1A2_Gaseous Fuels_CO2 (Approach 2)	b_AD_1A2_Liquid Fuels_CO2 (Approach 2)	t_AD_1A2_Liquid Fuels_CO2 (Approach 2)	b_AD_1A3b_Diesel_CO2 (Approach 2)	t_AD_1A3b_Diesel_CO2 (Approach 2)	b_AD_1A3b_Gasoline_CO2 (Approach 2)	t_AD_1A3b_Gasoline_CO2 (Approach 2)	b_AD_1A4a_Gaseous Fuels_CO2 (Approach 2)	t_AD_1A4a_Gaseous Fuels_CO2 (Approach 2)	b_AD_1A4a_Liquid Fuels_CO2 (Approach 2)	t_AD_1A4a_Liquid Fuels_CO2 (Approach 2)	b_AD_1A4b_Gaseous Fuels_CO2 (Approach 2)	t_AD_1A4b_Gaseous Fuels_CO2 (Approach 2)	b_AD_1A4b_Liquid Fuels_CO2 (Approach 2)	t_AD_1A4b_Liquid Fuels_CO2 (Approach 2)	b_EM_2F1__HFC (Approach 2)	t_EM_2F1__HFC (Approach 2)
b_AD_1A2_Gaseous Fuels_CO2 (Approach 2)	1.000	0.500							-0.500				-0.500					
t_AD_1A2_Gaseous Fuels_CO2 (Approach 2)		1.000								-0.500				-0.500				
b_AD_1A2_Liquid Fuels_CO2 (Approach 2)			1.000	0.500							-0.500				-0.500			
t_AD_1A2_Liquid Fuels_CO2 (Approach 2)				1.000								-0.500				-0.500		
b_AD_1A3b_Diesel_CO2 (Approach 2)					1.000	0.500												
t_AD_1A3b_Diesel_CO2 (Approach 2)						1.000												
b_AD_1A3b_Gasoline_CO2 (Approach 2)							1.000	0.500										
t_AD_1A3b_Gasoline_CO2 (Approach 2)								1.000										
b_AD_1A4a_Gaseous Fuels_CO2 (Approach 2)									1.000	0.500			-0.500					
t_AD_1A4a_Gaseous Fuels_CO2 (Approach 2)										1.000				-0.500				
b_AD_1A4a_Liquid Fuels_CO2 (Approach 2)											1.000	0.500			-0.500			
t_AD_1A4a_Liquid Fuels_CO2 (Approach 2)												1.000				-0.500		
b_AD_1A4b_Gaseous Fuels_CO2 (Approach 2)													1.000	0.500				
t_AD_1A4b_Gaseous Fuels_CO2 (Approach 2)														1.000				
b_AD_1A4b_Liquid Fuels_CO2 (Approach 2)															1.000	0.500		
t_AD_1A4b_Liquid Fuels_CO2 (Approach 2)																1.000		
b_EM_2F1__HFC (Approach 2)																	1.000	0.500
t_EM_2F1__HFC (Approach 2)																		1.000

Table A – 5 Correlation coefficients for CO_2 emission factors of category 1A1.

	b_EF_1A1_Other Fuels_CO2 (Approach 2)	t_EF_1A1_Other Fuels_CO2 (Approach 2)
b_EF_1A1_Other Fuels_CO2 (Approach 2)	1.000	0.500
t_EF_1A1_Other Fuels_CO2 (Approach 2)		1.000

Table A – 6 Correlation coefficients for emission factors of agricultural categories 3A, 3B, 3D, 3G and 3H.

	b_EF_3A_0_CH4 (Approach 2)	t_EF_3A_0_CH4 (Approach 2)	b_EF_3B_0_CH4 (Approach 2)	t_EF_3B_0_CH4 (Approach 2)	t_EF_3B_liquid_N2O (Approach 2)	b_EF_3B_solid_N2O (Approach 2)	t_EF_3B_solid_N2O (Approach 2)	b_EF_3B5_indirect_N2O (Approach 2)	t_EF_3B5_indirect_N2O (Approach 2)	b_EF_3Da1/2/4/5/7_fertilizer_N2O (Approach 2)	t_EF_3Da1/2/4/5/7_fertilizer_N2O (Approach 2)	b_EF_3Da6_organic soils_N2O (Approach 2)	t_EF_3Da6_organic soils_N2O (Approach 2)	b_EF_3Da3_0_N2O (Approach 2)	t_EF_3Da3_0_N2O (Approach 2)	b_EF_3Db1_deposition_N2O (Approach 2)	t_EF_3Db1_deposition_N2O (Approach 2)	b_EF_3Db2_leaching and runoff_N2O (Approach 2)	t_EF_3Db2_leaching and runoff_N2O (Approach 2)	b_EF_3G_0_CO2 (Approach 2)	t_EF_3G_0_CO2 (Approach 2)	b_EF_3H_0_CO2 (Approach 2)	t_EF_3H_0_CO2 (Approach 2)
b_EF_3A_0_CH4 (Approach 2)	1.000	1.000																					
t_EF_3A_0_CH4 (Approach 2)		1.000																					
b_EF_3B_0_CH4 (Approach 2)			1.000	1.000																			
t_EF_3B_0_CH4 (Approach 2)				1.000																			
t_EF_3B_liquid_N2O (Approach 2)					1.000																		
b_EF_3B_solid_N2O (Approach 2)						1.000	1.000																
t_EF_3B_solid_N2O (Approach 2)							1.000																
b_EF_3B5_indirect_N2O (Approach 2)								1.000	1.000														
t_EF_3B5_indirect_N2O (Approach 2)									1.000														
b_EF_3Da1/2/4/5/7_fertilizer_N2O (Approach 2)										1.000	1.000												
t_EF_3Da1/2/4/5/7_fertilizer_N2O (Approach 2)											1.000												
b_EF_3Da6_organic soils_N2O (Approach 2)												1.000	1.000										
t_EF_3Da6_organic soils_N2O (Approach 2)													1.000										
b_EF_3Da3_0_N2O (Approach 2)														1.000	1.000								
t_EF_3Da3_0_N2O (Approach 2)															1.000								
b_EF_3Db1_deposition_N2O (Approach 2)																1.000	1.000						
t_EF_3Db1_deposition_N2O (Approach 2)																	1.000						
b_EF_3Db2_leaching and runoff_N2O (Approach 2)																		1.000	1.000				
t_EF_3Db2_leaching and runoff_N2O (Approach 2)																			1.000				
b_EF_3G_0_CO2 (Approach 2)																				1.000	1.000		
t_EF_3G_0_CO2 (Approach 2)																					1.000		
b_EF_3H_0_CO2 (Approach 2)																						1.000	1.000
t_EF_3H_0_CO2 (Approach 2)																							1.000

Table A – 7 Correlation coefficients for activity data of the agricultural categories 3A, 3B and 3D.

	b_AD_3A_0_CH4 (Approach 2)	t_AD_3A_0_CH4 (Approach 2)	b_AD_3B_0_CH4 (Approach 2)	t_AD_3B_0_CH4 (Approach 2)	t_AD_3B_liquid_N2O (Approach 2)	b_AD_3B_solid_N2O (Approach 2)	t_AD_3B_solid_N2O (Approach 2)	b_AD_3B5_indirect_N2O (Approach 2)	t_AD_3B5_indirect_N2O (Approach 2)	b_AD_3Da1/2/4/5/7_fertilizer_N2O (Approach 2)	t_AD_3Da1/2/4/5/7_fertilizer_N2O (Approach 2)	b_AD_3Da6_organic soils_N2O (Approach 2)	t_AD_3Da6_organic soils_N2O (Approach 2)	b_AD_3Da3_0_N2O (Approach 2)	t_AD_3Da3_0_N2O (Approach 2)	b_AD_3Db1_deposition_N2O (Approach 2)	t_AD_3Db1_deposition_N2O (Approach 2)	b_AD_3Db2_leaching and runoff_N2O (Approach 2)	t_AD_3Db2_leaching and runoff_N2O (Approach 2)
b_AD_3A_0_CH4	1.000	0.500	0.500																
t_AD_3A_0_CH4 (Approa		1.000		0.500															
b_AD_3B_0_CH4 (Approach 2)			1.000	0.500															
t_AD_3B_0_CH4 (Approach 2)				1.000															
t_AD_3B_liquid_N2O (Approach 2)					1.000		-0.500										0.500		0.500
b_AD_3B_solid_N2O (Approach 2)						1.000										0.500		0.500	
t_AD_3B_solid_N2O (Approach 2)							1.000										0.500		0.500
b_AD_3B5_indirect_N2O (Approach 2)								1.000								0.500		0.500	
t_AD_3B5_indirect_N2O (Approach 2)									1.000								0.500		0.500
b_AD_3Da1/2/4/5/7_fertilizer_N2O (Approach 2)										1.000									
t_AD_3Da1/2/4/5/7_fertilizer_N2O (Approach 2)											1.000								
b_AD_3Da6_organic soils_N2O (Approach 2)												1.000							
t_AD_3Da6_organic soils_N2O (Approach 2)													1.000						
b_AD_3Da3_0_N2O (Approach 2)														1.000					
t_AD_3Da3_0_N2O (Approach 2)															1.000				
b_AD_3Db1_deposition_N2O (Approach 2)																1.000			
t_AD_3Db1_deposition_N2O (Approach 2)																	1.000		
b_AD_3Db2_leaching and runoff_N2O (Approach 2)																		1.000	
t_AD_3Db2_leaching and runoff_N2O (Approach 2)																			1.000

A2.2.4 Detailed Results of Monte Carlo Simulations

Table A – 8 Results of Approach 2 uncertainty analysis, Monte Carlo simulation (Table 3.3 of IPCC 2006 Guidelines, see also explanations therein on pp. 3.42-3.43 for each column)

Categories (NFR, fuel, gas)	Base year (1990) emissions/ removals	Year 2013 emissions/ removals	Activity data uncertainty		Emission factor/ estimation parameter uncertainty		Combined uncertainty		Contribution to variance in year 2013	Inventory trend in national emissions 1990-2013	Uncertainty introduced into the trend in total national emissions with respect to base year	
	kt CO2 eq	kt CO2 eq	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(fraction)	(% of base year)	(-) %	(+) %
1A1 Biomass CH4	0.45	0.41	-10	10	-28	28	-30	31	0.0000	-9	-41	40
1A1 Gaseous Fuels CH4	0.74	1.25	-5	5	-30	30	-30	30	0.0000	69	-59	59
1A1 Liquid Fuels CH4	0.59	0.82	-1	1	-30	30	-30	30	0.0000	40	-52	52
1A1 Solid Fuels CH4	0.12	-	-5	5	-30	30	NO	NO	-	-100	-30	30
1A1 Gaseous Fuels CO2	276.38	468.80	-5	5	-5	5	-7	7	0.0001	70	-13	13
1A1 Liquid Fuels CO2	693.69	945.83	-1	1	-1	1	-1	1	0.0000	36	-2	2
1A1 Other Fuels CO2	1'491.55	2'228.12	-10	10	-30	30	-31	32	0.0388	49	-42	43
1A1 Solid Fuels CO2	44.84	-	-5	5	-5	5	NO	NO	-	-100	-7	7
1A1 Biomass N2O	22.58	16.48	-10	10	-79	79	-79	81	0.0000	-27	-99	99
1A1 Gaseous Fuels N2O	0.15	0.25	-5	5	-80	80	-80	80	0.0000	69	-158	157
1A1 Liquid Fuels N2O	2.07	2.65	-1	1	-80	80	-80	80	0.0000	28	-130	130
1A1 Other Fuels N2O	24.33	13.05	-10	10	-79	79	-79	80	0.0000	-46	-91	90
1A1 Solid Fuels N2O	0.23	-	-5	5	-80	80	NO	NO	-	-100	-81	80
1A2 Biomass CH4	4.18	2.23	-10	10	-28	28	-29	31	0.0000	-47	-34	34
1A2 Gaseous Fuels CH4	3.13	5.99	-5	5	-30	30	-30	30	0.0000	92	-64	65
1A2 Liquid Fuels CH4	3.43	1.51	-1	1	-30	30	-30	30	0.0000	-56	-33	33
1A2 Other Fuels CH4	-	-	-10	10	-28	28	NO	NO	-	-	-	-
1A2 Solid Fuels CH4	0.34	0.19	-5	5	-30	30	-30	30	0.0000	-44	-34	34
1A2 Gaseous Fuels CO2	1'057.12	2'255.42	-5	5	-5	5	-7	7	0.0018	113	-14	14
1A2 Liquid Fuels CO2	3'875.05	2'274.91	-1	1	-1	1	-1	1	0.0001	-41	-1	1
1A2 Other Fuels CO2	134.16	312.93	-10	10	-30	30	-31	33	0.0008	133	-79	82
1A2 Solid Fuels CO2	1'155.82	490.74	-5	5	-30	30	-30	30	0.0017	-58	-33	33
1A2 Biomass N2O	3.91	13.26	-10	10	-79	79	-79	81	0.0000	239	-279	286
1A2 Gaseous Fuels N2O	0.56	1.18	-5	5	-80	80	-80	80	0.0000	111	-186	188
1A2 Liquid Fuels N2O	14.12	10.58	-1	1	-80	80	-80	80	0.0000	-25	-100	100
1A2 Other Fuels N2O	2.19	5.48	-10	10	-79	79	-79	81	0.0000	150	-214	218
1A2 Solid Fuels N2O	5.94	2.50	-5	5	-80	80	-80	81	0.0000	-58	-87	87
1A3a CH4	0.29	0.26	-1	1	-60	60	-60	60	0.0000	-10	-80	81
1A3a CO2	252.55	132.29	-1	1	-1	1	-2	2	0.0000	-48	-2	2
1A3a N2O	2.39	1.26	-1	1	-150	150	-151	150	0.0000	-47	-169	170
1A3b Biomass CH4	-	-0.04	-1	1	-60	60	60	-60	0.0000	-	-	-
1A3b Diesel CH4	1.64	0.66	-1	1	-20	20	-20	20	0.0000	-60	-22	21
1A3b Gaseous Fuels CH4	-	0.08	-5	5	-30	30	-30	30	0.0000	-	-	-
1A3b Gasoline CH4	116.05	21.00	-1	1	-37	37	-37	37	0.0000	-82	-38	37
1A3b Diesel CO2	2'587.68	7'137.84	-1	1	-0	0	-1	1	0.0005	176	-3	3
1A3b Gaseous Fuels CO2	-	62.60	-5	5	-5	5	-7	7	0.0000	-	-	-
1A3b Gasoline CO2	11'335.27	8'608.76	-1	1	-1	1	-2	2	0.0016	-24	-2	2
1A3b Biomass N2O	-	0.82	-1	1	-150	150	-150	150	0.0000	-	-	-
1A3b Diesel N2O	5.52	69.60	-1	1	-22	22	-22	22	0.0000	1'161	-280	279
1A3b Gaseous Fuels N2O	-	1.98	-5	5	-80	80	-80	80	0.0000	-	-	-
1A3b Gasoline N2O	136.89	22.82	-1	1	-50	50	-50	50	0.0000	-83	-51	51
1A3c Liquid Fuels CH4	0.01	0.01	-1	1	-30	30	-30	30	0.0000	37	-50	51
1A3c Liquid Fuels CO2	28.69	39.61	-1	1	-1	1	-1	1	0.0000	38	-2	2
1A3c Liquid Fuels N2O	0.37	0.50	-1	1	-150	150	-149	150	0.0000	38	-257	255
1A3d Liquid Fuels CH4	0.71	0.66	-1	1	-30	30	-30	30	0.0000	-8	-41	41
1A3d Liquid Fuels CO2	111.93	120.03	-1	1	-1	1	-1	1	0.0000	7	-2	2
1A3d Liquid Fuels N2O	1.21	1.32	-1	1	-150	150	-150	150	0.0000	9	-220	222
1A3e Gaseous Fuels CH4	0.07	0.03	-5	5	-30	30	-30	30	0.0000	-56	-33	33
1A3e Gaseous Fuels CO2	31.42	23.12	-5	5	-9	9	-10	10	0.0000	-26	-13	12
1A3e Gaseous Fuels N2O	0.02	0.01	-5	5	-80	80	-80	80	0.0000	-27	-100	100
1A4a Biomass CH4	9.23	4.05	-10	10	-28	28	-30	31	0.0000	-56	-33	32
1A4a Gaseous Fuels CH4	2.86	4.77	-5	5	-30	30	-30	30	0.0000	66	-58	58
1A4a Liquid Fuels CH4	3.41	1.73	-1	1	-30	30	-30	30	0.0000	-49	-34	34
1A4a Gaseous Fuels CO2	984.01	1'572.39	-5	5	-5	5	-7	7	0.0009	60	-11	11
1A4a Liquid Fuels CO2	4'260.88	3'286.01	-1	1	-1	1	-1	1	0.0001	-23	-1	1
1A4a Biomass N2O	3.50	8.59	-10	10	-79	79	-80	81	0.0000	145	-212	213
1A4a Gaseous Fuels N2O	0.52	0.83	-5	5	-80	80	-80	80	0.0000	59	-150	150
1A4a Liquid Fuels N2O	10.41	8.10	-1	1	-80	80	-80	80	0.0000	-22	-102	102

Categories (NFR, fuel, gas)	Base year (1990) emissions/ removals	Year 2013 emissions/ removals	Activity data uncertainty		Emission factor/ estimation parameter uncertainty		Combined uncertainty		Contribution to variance in year 2013	Inventory trend in national emissions 1990-2013	Uncertainty introduced into the trend in total national emissions with respect to base year	
	kt CO2 eq	kt CO2 eq	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(fraction)	(% of base year)	(-) %	(+) %
1A4b Biomass CH4	109.96	32.07	-10	10	-28	28	-29	31	0.0000	-71	-32	31
1A4b Gaseous Fuels CH4	3.94	7.87	-5	5	-30	30	-30	30	0.0000	99	-67	67
1A4b Liquid Fuels CH4	7.04	2.68	-1	1	-30	30	-30	30	0.0000	-62	-32	32
1A4b Solid Fuels CH4	4.73	3.00	-5	5	-30	30	-30	30	0.0000	-37	-36	35
1A4b Gaseous Fuels CO2	1'458.04	2'892.76	-5	5	-5	5	-7	7	0.0030	98	-13	14
1A4b Liquid Fuels CO2	10'099.18	7'334.47	-1	1	-1	1	-1	1	0.0005	-27	-1	1
1A4b Solid Fuels CO2	58.40	37.08	-5	5	-5	5	-7	7	0.0000	-36	-8	8
1A4b Biomass N2O	26.14	24.12	-10	10	-79	79	-79	81	0.0000	-8	-108	108
1A4b Gaseous Fuels N2O	0.77	1.53	-5	5	-80	80	-80	80	0.0000	97	-176	177
1A4b Liquid Fuels N2O	24.57	17.87	-1	1	-80	80	-79	80	0.0000	-27	-99	99
1A4b Solid Fuels N2O	0.30	0.19	-5	5	-80	80	-80	81	0.0000	-37	-95	94
1A4c Biomass CH4	1.97	0.41	-10	10	-28	28	-29	31	0.0000	-79	-31	30
1A4c Gaseous Fuels CH4	0.11	0.02	-5	5	-30	30	-30	30	0.0000	-86	-30	30
1A4c Liquid Fuels CH4	1.93	1.69	-1	1	-30	30	-30	30	0.0000	-12	-40	40
1A4c Gaseous Fuels CO2	41.45	5.96	-5	5	-5	5	-7	7	0.0000	-86	-7	7
1A4c Liquid Fuels CO2	547.34	513.86	-1	1	-1	1	-1	1	0.0000	-6	-2	2
1A4c Biomass N2O	0.51	0.79	-10	10	-79	79	-79	81	0.0000	54	-147	148
1A4c Gaseous Fuels N2O	0.02	0.00	-5	5	-80	80	-80	80	0.0000	-86	-81	82
1A4c Liquid Fuels N2O	4.76	5.28	-1	1	-80	80	-80	80	0.0000	11	-119	119
1A5 Liquid Fuels CH4	0.19	0.14	-1	1	-30	30	-30	30	0.0000	-27	-37	37
1A5 Liquid Fuels CO2	203.58	115.64	-1	1	-1	1	-1	1	0.0000	-43	-1	1
1A5 Liquid Fuels N2O	1.93	1.10	-1	1	-150	150	-150	149	0.0000	-43	-172	172
1B2 CH4	319.73	212.08	-5	5	-30	30	-30	30	0.0003	-34	-36	36
1B2 CO2	84.62	53.90	-5	5	-9	9	-10	10	0.0000	-36	-12	12
1B2 N2O	0.60	0.94	-5	5	-80	80	-80	80	0.0000	58	-151	149
2A1 CO2	2'524.45	1'811.87	-2	2	-2	2	-3	3	0.0002	-28	-3	3
2A2 CO2	53.35	51.06	-1	1	-1	1	-2	2	0.0000	-4	-3	3
2A3 CO2	15.25	6.49	-1	1	-1	1	-2	2	0.0000	-57	-2	2
2A4 CO2	156.15	85.84	-1	1	-51	51	-51	51	0.0001	-45	-58	58
2B CH4	1.83	2.12	-7	7	-29	29	-30	30	0.0000	16	-46	46
2B CO2	121.59	126.81	-7	7	-7	7	-10	10	0.0000	4	-14	14
2B N2O	65.49	27.11	-7	7	-40	40	-41	41	0.0000	-59	-44	44
2C1 CO2	9.20	10.34	-5	5	-40	40	-40	40	0.0000	12	-61	60
2C3 CO2	139.26	-	-7	7	-7	7	NO	NO	-	-100	-10	10
2C3 PFC	116.46	-	-6	6	-6	6	NO	NO	-	-100	0	0
2C4 SF6	-	42.07	-26	26	-26	26	-37	37	0.0000	-	-	-
2C7 CO2	1.65	1.30	-7	7	-7	7	-10	10	0.0000	-21	-13	13
2D CO2	72.79	100.78	-35	35	-35	35	-50	50	0.0002	38	-85	85
2E1 PFC	-	5.02	-43	43	-43	43	-60	61	0.0000	-	-	-
2E1 SF6	-	12.17	-40	40	-40	40	-57	57	0.0000	-	-	-
2E3 NF3	-	0.10	-65	65	-65	65	-93	93	0.0000	-	-	-
2E4 PFC	-	0.15	-43	43	-43	43	-60	61	0.0000	-	-	-
2F1 HFC	0.02	1'396.88	-12	12	-12	12	-17	17	0.0042	5'635'788	-931'498	939'596
2F1 PFC	0.05	8.22	-12	12	-12	12	-17	17	0.0000	15'222	-2'542	2'547
2F2 HFC	-	32.94	-10	10	-10	10	-15	15	0.0000	-	-	-
2F4 HFC	-	22.00	-29	29	-29	29	-41	41	0.0000	-	-	-
2F5 HFC	-	1.92	-39	39	-39	39	-55	55	0.0000	-	-	-
2G CO2	0.04	0.10	-35	35	-35	35	-50	50	0.0000	177	-147	147
2G HFC	-	66.15	-11	11	-11	11	-16	16	0.0000	-	-	-
2G PFC	-	38.61	-6	6	-6	6	-9	9	0.0000	-	-	-
2G SF6	137.01	198.21	-12	12	-12	12	-18	18	0.0001	45	-31	31
2G N2O	105.87	43.39	-35	35	-72	72	-80	80	0.0001	-59	-86	87
2H CO2	1.04	0.89	-7	7	-7	7	-10	10	0.0000	-14	-13	13
3A CH4	3'511.54	3'238.97	-6	6	-17	17	-17.8	18.4	0.0268	-8	-6	6
3B CH4	908.04	759.58	-6	6	-54	54	-54	54	0.0132	-16	-12	10
3B N2O	-	10.58	-32	32	-75	75	-76	89	0.0000	-	-	-
3B N2O	105.64	74.81	-32	32	-75	75	-77	90	0.0003	-29	-55	39
3B5 N2O	242.32	280.61	-38	55	-80	400	-77	125	0.0337	22	-53	80

Categories (NFR, fuel, gas)	Base year (1990) emissions/ removals	Year 2013 emissions/ removals	Activity data uncertainty		Emission factor/ estimation parameter uncertainty		Combined uncertainty		Contribution to variance in year 2013	Inventory trend in national emissions 1990-2013	Uncertainty introduced into the trend in total national emissions with respect to base year	
	kt CO2 eq	kt CO2 eq	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(fraction)	(% of base year)	(-) %	(+) %
3Da1/2/4/5/7 N2O	1'046.93	785.72	-15	15	-70	200	-64	87	0.0634	-25	-35	20
3Da6 N2O	69.28	66.69	-29	29	-75	200	-68	97	0.0005	-4	-49	46
3Da3 N2O	121.78	209.23	-53	84	-65	200	-68	114	0.0076	90	-95	164
3Db1 N2O	462.94	334.88	-33	46	-80	400	-76	122	0.0449	-25	-59	34
3Db2 N2O	195.11	146.39	-23	22	-93	233	-77	102	0.0032	-	-	-
3G CO2	22.57	32.58	-40	40	-5	5	-40	40	0.0000	44	-70	70
3H CO2	26.71	9.45	-5	5	-5	5	-7	7	0.0000	-65	-6	6
5A CH4	923.53	191.70	-10	10	-50	50	-51	51	0.0007	-79	-52	52
5A CO2	9.04	-	-10	10	-25	25	NO	NO	-	-100	-27	27
5B CH4	81.83	468.63	-10	10	-40	40	-41	41	0.0029	473	-240	240
5B N2O	5.66	25.65	-10	10	-79	79	-80	80	0.0000	353	-373	373
5C CH4	13.79	7.17	-10	10	-10	10	-14	14	0.0000	-48	-16	16
5C CO2	53.73	9.82	-10	10	-40	40	-41	41	0.0000	-82	-42	42
5C N2O	18.32	28.11	-10	10	-10	10	-14	14	0.0000	53	-26	26
5D CH4	130.92	173.34	-36	36	-32	32	-48	48	0.0005	32	-80	80
5D N2O	117.87	148.54	-32	32	-147	147	-150	149	0.0039	26	-243	240
6 CH4	0.66	0.68	-2	2	-60	60	-60	60	0.0000	2	-86	86
6 CO2	10.96	12.92	-2	2	-40	40	-40	40	0.0000	18	-62	62
6 N2O	0.60	0.60	-2	2	-150	150	-151	150	0.0000	0	-213	212
4 II CH4	10.75	10.75	-10	10	-70	70	-71	71	0.0000	0	-100	101
4 II N2O	6.91	7.01	-30	30	-138	138	-140	140	0.0000	1	-201	201
4 III N2O	61.10	53.05	-6	6	-135	135	-134	134	0.0004	-13	-178	177
4 IV N2O	13.75	11.94	-32	32	-162	162	-165	166	0.0000	-14	-219	217
4 V CH4	25.36	0.54	-10	10	-70	70	-71	71	0.0000	-98	-71	71
4 V CO2	25.36	0.55	-10	10	-70	70	-71	71	0.0000	-98	-70	71
4 V N2O	4.77	0.09	-10	10	-70	70	-71	71	0.0000	-98	-71	71
4A1 CO2	-2'342.87	-2'258.41	-2	2	-45	45	45	-45	0.0806	-4	63	-63
4A2 CO2	-621.02	-425.44	-2	2	-45	45	45	-45	0.0029	-31	55	-55
4B1 CO2	364.73	842.28	-5	5	-88	88	-87	88	0.0422	131	-221	221
4B2 CO2	47.60	24.16	-6	6	-129	129	-130	129	0.0001	-49	-145	145
4C1 CO2	86.70	121.07	-6	6	-2'316	2'316	-2'252	2'260	0.6103	46	-4'025	4'048
4C2 CO2	49.75	159.18	-6	6	-72	72	-73	73	0.0010	220	-243	245
4D1 CO2	3.14	55.61	-30	30	-100	100	-105	105	0.0003	1'666	-1'858	1'856
4D2 CO2	20.64	29.57	-5	5	-50	50	-50	51	0.0000	44	-88	88
4E1 CO2	20.05	57.19	-5	5	-50	50	-50	50	0.0001	185	-153	152
4E2 CO2	394.80	307.51	-5	5	-50	50	-50	50	0.0019	-22	-64	63
4F2 CO2	93.93	115.18	-4	4	-50	50	-50	50	0.0003	23	-80	80
4G CO2	-1'218.45	-147.91	-3	3	-57	57	57	-57	0.0006	-88	58	-57
incl LULUCF	**50'355**	**51'525**					**-6.71**	**6.85**		**2.08**	**-7.97**	**7.99**
excl. LULUCF	**53'308**	**52'561**					**-3.22**	**3.53**		**-1.54**	**-2.53**	**2.47**

A2.2.5 Relation between simulated and inventory values

The Monte Carlo method simulates a probability distribution of the Swiss greenhouse gas emissions from which all relevant statistical parameters can be derived (mean, standard deviation and percentiles). The simulated mean value may slightly differ from the reported value.

The discrepancy between simulated and reported values becomes apparent when mean numbers in Figure 1-3 are compared to reported numbers in the summary tables. Note that it is not a relevant issue for the uncertainty analysis but can be confusing for readers and reviewers who carefully study the numbers. For transparency reasons, the numbers are explained in Table A – 9.

The absolute percentiles generated by the simulation are firstly expressed as relative numbers (the simulated mean is set to 100%). Then the relative numbers are transferred to the numbers reported in the summary tables, then they are applied to derive the absolute uncertainties.

Table A – 9 Mean values, 2.5 and 97.5 percentiles of the Monte Carlo simulation and corresponding values of the reported emissions (as listed in summary tables).

Year	Parmeters	Unit	Emission (excl. LULUCF)	Lower bound 2.5 percentile	Upper bound 97.5 percentile	Lower uncertainty	Upper uncertainty
2013	**simulated values**						
	absolute	kt CO_2 eq	53'844	52'109	55'745	-1'735	1'901
	relative	%	100.00%	96.78%	103.53%	-3.22%	3.53%
	reported values						
	absolute	kt CO_2 eq	52'561	50'868	54'417	-1'693	1'856
	relative	%	100.00%	96.78%	103.53%	-3.22%	3.53%
1990	**simulated values**						
	absolute	kt CO_2 eq	54'688	52'745	56'845	-1'943	2'157
	relative	%	100.00%	96.45%	103.94%	-3.55%	3.94%
	reported values						
	absolute	kt CO_2 eq	53'308	51'414	55'411	-1'894	2'103
	relative	%	100.00%	96.45%	103.94%	-3.55%	3.94%

Annex 3: Other detailed methodological descriptions for individual source or sink categories

A3.1 Sector Energy

A3.1.1 Emission from Manufacturing Industries and Construction

The emission factors of precursors in the manufacturing industries and construction sector are given below. Emission factors for greenhouse gases are given in 3.2.6.2.

Table A – 10 Emission factors of precursors from Manufacturing Industries and Construction

1A2 Emission factors (mix of bottom-up and top-down approach (modelling))	**NO_x**	**CO**	**NMVOC**	**SO_2**
	kg/TJ	kg/TJ	kg/TJ	kg/TJ
1A2a Iron and steel				
Gas oil	32	7	2	21
Liquefied petroleum gas	32	7	2	21
Residual fuel oil	NO	NO	NO	NO
Petroleum coke	NO	NO	NO	NO
Other bituminous coal	NO	NO	NO	NO
Lignite	NO	NO	NO	NO
Natural gas	9	4	1	0.0
1A2b Non-ferrous metals				
Gas oil	32	7	2	21
Liquefied petroleum gas	32	7	2	21
Residual fuel oil	125	12	4	0.0
Petroleum coke	NO	NO	NO	NO
Other bituminous coal	NO	NO	NO	NO
Lignite	NO	NO	NO	NO
Natural gas	19	9	2	0.5
1A2c Chemicals				
Gas oil	32	7	2	21
Liquefied petroleum gas	32	7	2	21
Residual fuel oil	125	12	4	291
Petroleum coke	NO	NO	NO	NO
Other bituminous coal	NO	NO	NO	NO
Lignite	NO	NO	NO	NO
Natural gas	19	9	2	0.5
Other fossil fuels	NO	NO	NO	NO
1A2d Pulp, paper and print				
Gas oil	32	7	2	21
Liquefied petroleum gas	32	7	2	21
Residual fuel oil	125	12	4	291
Petroleum coke	NO	NO	NO	NO
Other bituminous coal	NO	NO	NO	NO
Lignite	NO	NO	NO	NO
Natural gas	19	9	2	0.5
1A2e Food processing, beverages and tobacco				
Gas oil	32	7	2	21
Liquefied petroleum gas	32	7	2	21
Residual fuel oil	NO	NO	NO	NO
Petroleum coke	NO	NO	NO	NO
Other bituminous coal	NO	NO	NO	NO
Lignite	NO	NO	NO	NO
Natural gas	19	9	2	0.5
1A2f Non-metallic minerals				
Fuels, not itemized (fine ceramics, glass, glass wool, bottle glas, lime, asphalt, rock wool, brick, cement)	233	420	22	121
1A2g Other				
Gas oil	32	7	7	21
Liquefied petroleum gas	32	7	2	21
Residual fuel oil	125	12	4	291
Petroleum coke	200	100	10	500
Other bituminous coal	200	100	10	500
Lignite	212	100	10	500
Natural gas	23	10	3	1
Biomass	121	234	6	16
Gasoline and gas oil	407	795	71	0.5

A3.1.2 Civil Aviation

This paragraph contains further information on the emission modelling. More complete information is provided in FOCA (2006-2014) and on request for reviewers by FOCA.

Emission factors

Table A – 11 Aircraft cruise factors, used for cruise emission calculation (extract of list of 881 aircraft) GKL_ICAO = ICAO seat categories. Mass emissions are given in kilograms or grams per nautical mile (NM).

Aircraft Cruise _Factors						
Aircraft_ICAO	GKL_ICAO	Cruise_D_Source	kg_fuel_NM	kg_NOx_NM	g_VOC_NM	g_CO_NM
AA1	0	P002FOCA	0.21	0.0098	1.79	61.7
AA5	0	P002FOCA	0.21	0.0098	1.79	61.7
AC11	0	P002FOCA	0.21	0.0098	1.79	61.7
AC14	0	P002FOCA	0.21	0.0098	1.79	61.7
AC50	0	P001FOCA	0.77	0.021	4.14	364.17
AC68	0	P001FOCA	0.77	0.0075	4.14	364.17
AC6T	1	FOCAINV95-03.2T	1.58	0.021	0.87	2.9
AC90	1	FOCAINV95-03.2T	1.58	0.021	0.87	2.9
AC95	1	FOCAINV95-03.2T	1.58	0.021	0.87	2.9
AEST	0	P001FOCA	0.77	0.021	4.14	364.17
AJET	0	FOCAEDBJ014	2.92	0.0146	8.53	63
ALO2	0	FOCAHeli	1.91	0.024	0.42	2.1
ALO3	0	FOCAHeli	1.91	0.024	0.42	2.1
AN12	0	AN26*2	5.36	0.0062	143	348
AN2	0	FOCA/91/DC3	0.82	0.0002	13.7	1000
AN22	6	FOCAINV95-03.2T*2	3.16	0.042	1.74	5.8
AN24	2	AN26	2.68	0.0031	71.7	174
AN26	1	500	2.68	0.0031	71.7	174
AN72	2	FOCAINV95-03.2J	6.4	0.1	0.83	10
AR7	0	P002FOCA	0.21	0.0098	1.79	61.7
AR7A	0	P002FOCA	0.21	0.0098	1.79	61.7
AS02	0	P002FOCA	0.21	0.0098	1.79	61.7
AS16	0	P002FOCA	0.21	0.0098	1.79	61.7
AS20	0	P002FOCA	0.21	0.0098	1.79	61.7
AS24	0	P002FOCA	0.21	0.0098	1.79	61.7
AS25	0	P002FOCA	0.21	0.0098	1.79	61.7
AS26	0	P002FOCA	0.21	0.0098	1.79	61.7
AS2T	0	FOCAEDBT758	0.95	0.005	1.8	12
AS30	0	FOCAHeli*2	3.82	0.048	0.82	4.2
AS32	1	FOCAHeli*2	3.82	0.048	0.82	4.2
AS33	0	FOCAHeli*2	3.82	0.048	0.82	4.2
AS35	0	FOCAHeli	1.91	0.024	0.42	2.1
AS50	0	FOCAHeli*2	3.82	0.048	0.82	4.2
AS55	0	FOCAHeli*2	3.82	0.048	0.82	4.2
AS65	0	FOCAHeli*2	3.82	0.048	0.82	4.2
ASK1	0	P002FOCA	0.21	0.0098	1.79	61.7
ASTA	0	FOCAINV95-03.B	3.016	0.046	0.3	2.8
ASTR	0	FOCAINV95-03.B	3.016	0.046	0.3	2.8
ASTRA	0	FOCAINV95-03.B	3.016	0.046	0.3	2.8
AT42	1	FOCAINV95-03.2T	1.58	0.021	0.87	2.9
AT43	1	500	1.6	0.013	0	15

Activity Data

LTO-cycle times (minutes). ICAO standard cycle times were originally designed for emissions certification, not for emissions modelling. Today, they do generally not match real world aircraft LTO operations. Swiss FOCA has therefore adjusted some of the ICAO standard cycle times for different aircraft categories. For jets, the mean time for taxi-in and taxi-out at Swiss airports has been determined 20 minutes instead of the standard 26 minutes.

Table A – 12 For jets, business jets, turboprops, piston engines and helicopters, the times in mode are shown and are based on ICAO, US EPA and Swiss FOCA data. “Type” is a classification variable. J = Jet, T = Turboprop, P = Piston, H = Helicopter, B = Business jet, SJ = Supersonic Jet. The number in “Type” stands for the number of engines. For Jet Aircraft, the cycle times and associated thrust settings still lead to an overestimation of LTO emissions (FOCA 2007b).

LTO Cycle				
Type	Time_Take_Off	Time_Climbout	Time_Approach	Zeit_Taxi
1J	0.7	2.2	4	20
1T	0.5	2.5	4.5	13
1P	0.3	2.5	3	12
1H	0	6.5	6.5	7
2B	0.4	0.5	1.6	13
3B	0.4	0.5	1.6	13
2T	0.5	2.5	4.5	13
4T	0.5	2.5	4.5	13
2J	0.7	2.2	4	20
3J	0.7	2.2	4	20
4J	0.7	2.2	4	20
2P	0.3	2.5	3	12
3P	0.3	2.5	3	12
4P	0.3	2.5	3	12
2H	0	6.5	6.5	7
4SJ	1.2	2	2.3	20
3H	0	6.5	6.5	7
4H	0	6.5	6.5	7
4B	0.4	0.5	1.6	13

Table A – 13 Aircraft-Engine Combinations and associated codes for SWISS FOCA emissions database. (Extract from list of more than 26'000 individual aircraft)

Aircraft Engine Combinations							
Engine Name	Aircraft Name	Aircraft Registr.	No. Eng.	Code	Type	Aircr. ICAO	Source
V2527-A5	AIRBUS A320-232	ECHXA	2	J220	2J	A320	1IA003
CF34-3B1	BOMBARDIER CRJ200ER (CL-600-2B19)	ECHXM	2	J090	2J	CRJ2	1GE034
CFM56-3C1	BOEING 737-4K5	ECHXT	2	J022	2J	B734	1CM007
TPE331-11U-611G	FAIRCHILD (SWEARIN-GEN) SA227AC METR	ECHXY	2	T310	2T	SW4	FOI
CFM56-5B4/P	AIRBUS A320-214	ECHYC	2	J067	2J	A320	3CM026
CFM56-5B4/P	AIRBUS A320-214	ECHYD	2	J067	2J	A320	3CM026
CF34-3B1	BOMBARDIER CRJ200ER (CL-600-2B19)	ECHYG	2	J090	2J	CRJ2	1GE034
CFEC-FE738-1-1B	DASSAULT FALCON 2000	ECHYI	2	B130	2B	F2TH	FOI-Ho-neywell
GA TPE331-11U-612G		ECHZH	2	T310	2T	FA3	FOI
CF34-3B1	BOMBARDIER CRJ200ER (CL-600-2B19)	ECHZR	2	J090	2J	CRJ2	1GE034
CFM56-7B27B1	BOEING 737-86Q (WINGLETS)	ECHZS	2	J075	2J	B738	3CM034
CFM56-5B4/P	AIRBUS A320-214	ECHZU	2	J067	2J	A320	3CM026
CF34-3B1	BOMBARDIER CRJ200ER (CL-600-2B19)	ECIAA	2	J090	2J	CRJ2	1GE034
FJ44-1A	CESSNA 525 CITATIONJET	ECIAB	2	B001	2B	C525	FOCA
CFM56-5B4/P	AIRBUS A320-214	ECIAG	2	J067	2J	A320	3CM026
V2527-A5	AIRBUS A320-232	ECIAZ	2	J220	2J	A320	1IA003
BRBR700-710A2-20	BOMBARDIER BD-700-1A10 GLOBAL EX-PRE	ECIBD	2	J854	2J	GLEX	4BR009
PT6A-60A	BEECH-CRAFT KING AIR 350 (RAYTHEON B	ECIBK	2	T738	2T	B350	FOI
CF34-3B1	BOMBARDIER CRJ200ER (CL-600-2B19)	ECIBM	2	J090	2J	CRJ2	1GE034
CFM56-7B27B1	BOEING 737-81Q (WINGLETS)	ECICD	2	J075	2J	B738	3CM034
CFM56-5B4/P	AIRBUS A320-214	ECICK	2	J067	2J	A320	3CM026

Emissions

The output of the FOCA emission modelling consists of tables with the following structure:

Table A – 14 Extract of the output file of FOCA emission and fuel consumption modelling. Upper part: LTO, lower part: cruise (example for 2004). Emissions and fuel consumption in tons.

Airport	Distance	Type Traffic	Move-ments	Type	Aircraft ICAO	Engine Name	Fuel (LTO) tons	Emissions (LTO) in tons					
	Km		No.					CO_2	H_2O	SO_2	NO_x	VOC	CO
LSGG	181501.69	Taxi	165	2B	C550	JT15D-4	5673.492	17871.5	6978.395	5.673	26.04	139	359.2
LSGG	164165.197	Taxi	77	2J	B752	RB211-535E4	47470.5	149532.1	58388.72	47.47	554.91	0	361.47
LSGG	133166.837	Taxi	118	2B	F2TH	CFE738-1-1B	6164.2728	19417.46	7582.056	6.164	87.539	40.59	185.53
LSGG	117228.943	Taxi	99	3B	F900	TFE731-60-1C	5668.542	17855.91	6972.307	5.669	46.937	28.13	163.44
LSGG	114258.902	Taxi	134	2B	LJ45	TFE731-20R	4725.108	14884.09	5811.883	4.725	31.31	53.62	169.01
LSGG	112510.267	Taxi	100	2B	F2TH	CFE738-1-1B	5223.96	16455.47	6425.471	5.224	74.186	34.4	157.23
LSGG	107945.477	Taxi	96	2B	C560	JT15D-5D	3795.3216	11955.26	4668.246	3.795	16.959	271.6	287.98
LSGG	181501.69	Taxi	165	2B	C550	JT15D-4	307732.68	969357.9	378511.2	307.7	4513	29.43	274.71
LSGG	164165.197	Taxi	77	2J	B752	RB211-535E4	673698.47	2122150	828649.1	673.7	7986.4	647.8	1038.2
LSGG	133166.837	Taxi	118	2B	F2TH	CFE738-1-1B	225781.85	711212.8	277711.7	225.8	3311.2	21.59	201.55
LSGG	117228.943	Taxi	99	3B	F900	TFE731-60-1C	298139.18	939138.4	366711.2	298.1	4372.3	28.52	266.14
LSGG	114258.902	Taxi	134	2B	LJ45	TFE731-20R	193723.81	610230	238280.3	193.7	2841	18.53	172.93
LSGG	106761.289	Taxi	100	2B	F2TH	CFE738-1-1B	181011.75	570187	222644.4	181	2654.6	17.31	161.58
LSGG	103217.159	Taxi	96	2B	C560	JT15D-5D	175002.74	551258.6	215253.4	175	2566.5	16.74	156.22

A3.1.3 Road Transportation

Emission factors

The derivation of the emission factors for road vehicles is described in detail in INFRAS 2010 (this report is available in English). Some important features of the emission factor methodologies are summarised in this paragraph.

The emission factors have to be differentiated according to vehicle categories. Each category contains a number of vehicle classes, which differ by emission concepts. The next table illustrates the classes of the passenger cars. Similar “segmentations” hold for the other vehicle categories too. Emission factors for vehicle classes are combined to average emission factors for vehicles categories weighted according to the fleet composition, which varies from year to year (see below).

Table A – 15 Vehicle segmentation of the passenger cars. Each segment is subdivided into three cubic capacities: <1.4 litre, 1.4-2.0 litres, > 2.0 litres (INFRAS 2010).

Fuel type	Vehicle segment
Gasoline	<ECE
	AGV82 (CH)
	PreEuro 3WayCat <1987
	PreEuro 3WayCat 1987-90
	ECE-15'00
	ECE-15'01/02
	ECE-15'03
	Euro-1
	Euro-2
	Euro-3
	Euro-4
	Euro-5
	Euro-6
Diesel	<1986
	1986-1988
	Euro-1
	Euro-2
	Euro-3
	Euro-4
	Euro-5 Diesel Particle Filter
	Euro-6 Diesel Particle Filter

The emission factors published in the handbook (CD ROM, INFRAS 2010) are classified by “traffic situations”. The scheme (see table below) distinguishes the traffic situations along 4 dimensions: urban/rural areas, 5 functional road types, speed limit and 4 levels of service. This leads to the definition of 276 different traffic situations in total. A traffic situation is primarily characterised by the type of road which induces a typical driving behaviour. (Because driving behaviour is not independent of the amount of traffic on that particular road, on the same segment different driving patterns may exist.) For the handbook several typical traffic situations have been defined, based on driving behaviour studies in Germany and in Switzerland (see e.g. SAEFL 1995, Chp. 4).

Table A – 16 Traffic situation-scheme in HBEFA 3.1 (INFRAS 2010). Every traffic situation is characterised by a typical driving pattern (i.e. a speed-time curve)

			Speed Limit [km/h]											
Area	**Road type**	**Levels of service**	30	40	50	60	70	80	90	100	110	120	130	>130
Rural	**Motorway-Nat.**	**4 levels of service**												
	Semi-Motorway	**4 levels of service**												
	TrunkRoad/Primary-Nat.	**4 levels of service**												
	Distributor/Secondary	**4 levels of service**												
	Distributor/Secondary(sinuous)	**4 levels of service**												
	Local/Collector	**4 levels of service**												
	Local/Collector(sinuous)	**4 levels of service**												
	Access-residential	**4 levels of service**												
Urban	**Motorway-Nat.**	**4 levels of service**												
	Motorway-City	**4 levels of service**												
	TrunkRoad/Primary-Nat.	**4 levels of service**												
	TrunkRoad/Primary-City	**4 levels of service**												
	Distributor/Secondary	**4 levels of service**												
	Local/Collector	**4 levels of service**												
	Access-residential	**4 levels of service**												

Traffic situations are defined independently of vehicle categories (LDV, HDV, 2-wheelers). But behind the same traffic situation each vehicle category may know its own “driving pattern” which may be expressed as a speed curve (i.e. speed time series). Emission factors originally are derived for these underlying driving patterns based on measurements performed on laboratory test benches. Emission factors per traffic situation are then calculated by attributing the driving patterns to different traffic situations (based on statistical analyses).

Emission factors for Switzerland are shown in the next table (FOEN 2010i, updated based on Prognos 2012a). They represent weighted averages over all traffic situations. The year indicates the date when the corresponding vehicle class appears in the market. E.g. “Euro-3” standard came into force on 1 Jan, 2001, but the first vehicles with Euro-3 standard already appeared in 1999.

Table A – 17 14 Mean emission factors of passenger cars (PC), light duty vehicles (LDV), heavy duty vehicles (HDV), coaches, urban buses (Bus) and Motorcycles (MC) in grams per kilometre, incl. cold starts and evaporation. (FOEN 2010i, updated based on Prognos 2012a). CO_2 (rep.) refers to the fossil part, CO_2 (total) includes fossil and biomass.HC and NMHC corresponds to VOC and NMVOC.

Pollutant	Year	PC	LDV	HDV	Coach	Bus	MC
grams per vehicle kilometre, incl. cold starts and evaporation							
CH_4	1990	0.080	0.090	0.020	0.017	0.053	0.236
CH_4	1995	0.050	0.065	0.018	0.016	0.046	0.159
CH_4	2000	0.033	0.039	0.013	0.014	0.034	0.120
CH_4	2005	0.021	0.020	0.009	0.011	0.018	0.103
CH_4	2010	0.013	0.012	0.004	0.007	0.005	0.092
CH_4	2015	0.009	0.006	0.002	0.004	0.003	0.082
CO	1990	9.58	20.16	2.39	2.09	5.99	14.70
CO	1995	5.46	14.60	2.18	2.01	5.68	14.14
CO	2000	3.59	8.86	1.77	1.84	4.64	13.62
CO	2005	2.53	4.39	1.61	1.73	2.92	11.68
CO	2010	1.64	2.09	1.44	1.70	1.26	8.09
CO	2015	1.19	1.28	1.27	1.63	1.03	5.63
CO_2(rep.)	1990	234	249	803	871	1'194	82
CO_2(rep.)	1995	237	252	799	860	1'199	90
CO_2(rep.)	2000	230	254	759	833	1'162	92
CO_2(rep.)	2005	217	246	790	823	1'127	94
CO_2(rep.)	2010	195	237	768	812	1'078	96
CO_2(rep.)	2015	169	224	739	794	1'045	91
CO_2(total)	1990	234	249	803	871	1'194	82
CO_2(total)	1995	237	252	799	860	1'199	90
CO_2(total)	2000	230	255	760	834	1'163	92
CO_2(total)	2005	217	246	793	826	1'131	94
CO_2(total)	2010	199	240	777	821	1'094	99
CO_2(total)	2015	180	232	760	817	1'079	98
HC	1990	1.58	2.02	0.85	0.70	2.20	3.69
HC	1995	0.92	1.38	0.74	0.66	1.93	2.65
HC	2000	0.57	0.77	0.56	0.60	1.42	2.08
HC	2005	0.36	0.38	0.38	0.47	0.73	1.64
HC	2010	0.23	0.19	0.16	0.27	0.22	1.19
HC	2015	0.17	0.12	0.07	0.16	0.12	0.85
N_2O	1990	0.009	0.005	0.008	0.008	0.003	0.002
N_2O	1995	0.012	0.007	0.009	0.008	0.003	0.002
N_2O	2000	0.011	0.009	0.009	0.008	0.003	0.002
N_2O	2005	0.005	0.007	0.008	0.007	0.002	0.002
N_2O	2010	0.003	0.006	0.030	0.014	0.001	0.002
N_2O	2015	0.002	0.005	0.041	0.023	0.002	0.002
N_2O	2020	0.002	0.005	0.043	0.029	0.005	0.002
N_2O	2025	0.002	0.005	0.043	0.032	0.008	0.002
N_2O	2030	0.002	0.004	0.042	0.033	0.009	0.002
N_2O	2035	0.002	0.004	0.042	0.033	0.010	0.002
N_2O	2040	0.002	0.004	0.041	0.033	0.010	0.002
N_2O	2045	0.002	0.004	0.041	0.033	0.010	0.002
N_2O	2050	0.002	0.003	0.041	0.032	0.010	0.002
NMHC	1990	1.504	1.930	0.827	0.681	2.151	3.451
NMHC	1995	0.871	1.320	0.721	0.640	1.880	2.489
NMHC	2000	0.538	0.735	0.543	0.582	1.383	1.964
NMHC	2005	0.343	0.362	0.373	0.459	0.714	1.538
NMHC	2010	0.217	0.180	0.155	0.265	0.209	1.096
NMHC	2015	0.163	0.116	0.069	0.156	0.110	0.773
NO_x	1990	2.147	4.167	22.457	22.929	33.896	0.294
NO_x	1995	1.608	3.485	20.751	21.648	32.841	0.392
NO_x	2000	1.301	3.067	18.148	19.938	29.997	0.423
NO_x	2005	0.968	2.595	15.051	17.360	24.703	0.444
NO_x	2010	0.679	2.117	9.512	13.381	18.000	0.400
NO_x	2015	0.535	1.857	6.213	10.142	13.576	0.352
SO_2	1990	0.040	0.093	0.714	0.774	1.061	0.010
SO_2	1995	0.031	0.041	0.173	0.186	0.260	0.011
SO_2	2000	0.022	0.034	0.131	0.144	0.201	0.008
SO_2	2005	0.001	0.001	0.005	0.005	0.007	0.000
SO_2	2010	0.001	0.001	0.005	0.005	0.007	0.001
SO_2	2015	0.001	0.001	0.005	0.005	0.006	0.001

Activity Data

Activity data for the emission model are the mileages of the vehicle categories per traffic situation. To that aim, three steps must be carried out.

1. Vehicle turnover: The vehicle fleet is built up for each year accounting for the stock changes. This vehicle turnover is modelled on the basis of new registrations and by applying survival probabilities. Trends in traffic volume per vehicle category, including structural changes (size distributions, shares of diesel vehicles) are then combined to draw the continual substitution of older technologies by new ones constantly altering the fleet composition or mileage by emission concepts in all vehicle categories (see following Figure A-1).

2. The total mileage is calculated by vehicle stock multiplied with the specific mileage per vehicle and annum. The latter data are derived from surveys and from specific odometer readings during vehicle inspections (ARE 2002).

3. Assignment of the mileage to the traffic situations for all vehicle categories. This step requires the adoption of the traffic model: Each road segment carries its mileage and its traffic, which allows the assignment sought.

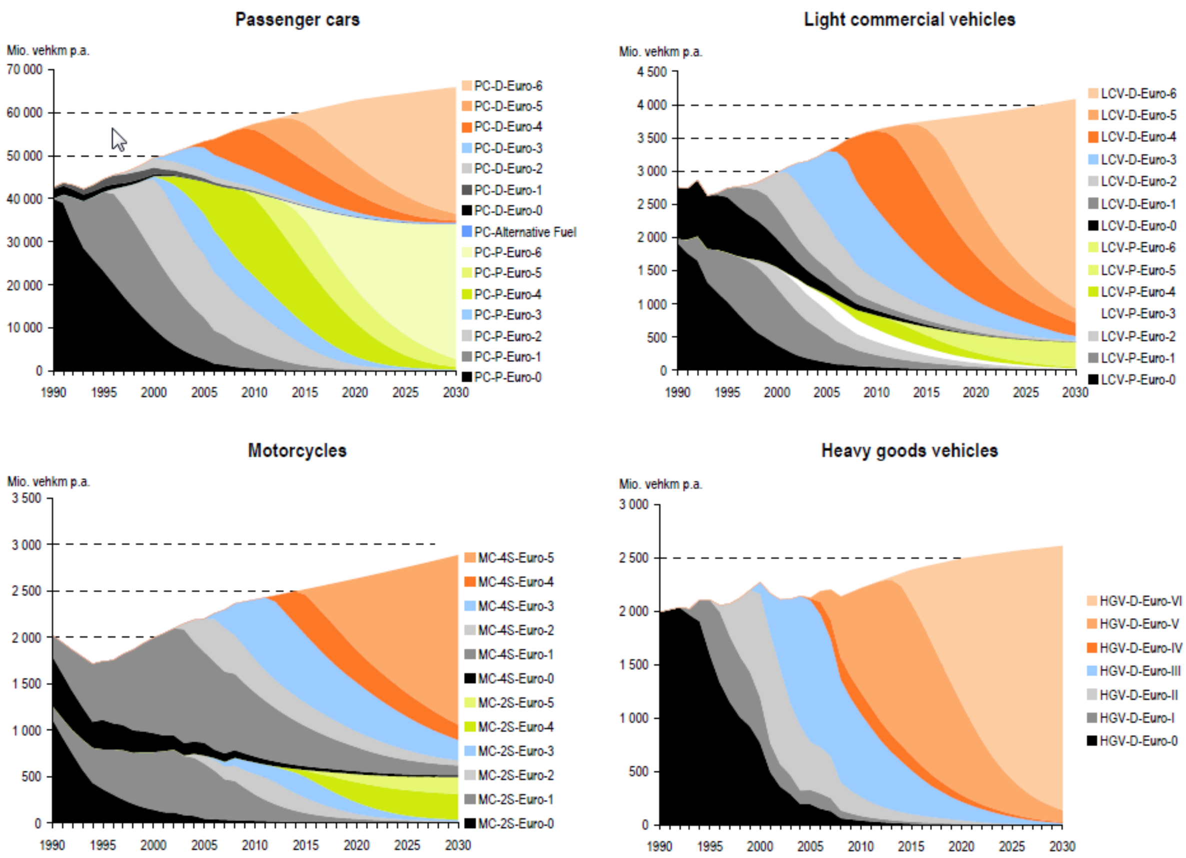


Figure A – 1 Mileage composition by emission concept (in million vehicle kilometres per year), FOEN 2010i.

Modelling hot exhaust emissions

As a next step in the modelling process, the mileage classified by vehicle segments and traffic situations is multiplied with the emission factors resulting in hot exhaust emissions.

The results do not yet contain the emissions from fuel tourism and statistical differences. For this purpose a special procedure is carried out (described in section 3.2.7.2b), providing the fuel consumption of fuel tourism and statistical differences. From that, the emissions are calculated by multiplication with mean emission factors.

Cold start and evaporative emissions

The handbook also contains emission factors for modelling cold start excess emissions and evaporative emissions (diurnal and hot/warm soak and running losses). For a technical description the reader may refer to INFRAS (2010).

Results show that for CO_2 the hot exhaust emissions contribute to 97% of the total. Only 3% stem from cold start excess emissions. For CH_4 however, the picture is different. Only about 40% of the emission total is hot exhaust. More than 59% are cold start excess emissions, the rest results evaporative emissions. For N_2O, no cold start emissions or evaporative emissions are taken into account due to lack of data.

A3.1.4 Non-road Vehicles

Methodology

The emissions of the whole non-road sector underwent a complete revision for submission 2010. The emissions are calculated with a Tier 2 method. Activity data and emission factors were updated for submission 2010; for the present Submission, activity data have again been recalculated following the update of the latest figures on population and economy (Prognos 2012a). The modelling is carried out in a database (INFRAS 2008) that is structured in analogy to the on-road database (INFRAS 2010). The non-road sector has been allocated to 1A2, 1A3 and 1A4, with only military non-road remaining in 1A5.

The modelling of the emission and of the fuel consumption are carried out by using the formula

$$E^{g}_{i,j,t,\tau} = N_{i,j,t} \cdot T_{i,j,t} \cdot \omega_{t-\tau} \cdot P_{i,j} \cdot L_{i,j} \cdot \nu_{t-\tau} \cdot \varepsilon^{g}_{i,j,\tau}$$

E: Emission and fuel consumption

N: number of vehicles

T: average operating hours per year

ω: age dependency

P: motor power in kW

L: load factor

ν: degradation factor (due to aging)

ε emission factor in g/kWh

indices: g: gas (CH_4, N_2O, CO, NOx, SO_2) and fuel consumption,

i non-road family (railway, navigation etc.),

j size class,

t: year (1980, 1985, 1990, 1995, 2000, … , 2020)

τ: year of construction (note: t - τ = age of vehicle)

Note that the emissions are only calculated in steps of 5 years. Emissions for years in-between like 1991, 1992 etc. are interpolated linearly.

Emission and fuel consumption factors for non-road vehicles

The CO_2 emission factors are derived from fuel type and fuel consumption (see tables below). The emission factors for CH_4 and N_2O are only specified by the fuel type.

Table A – 18 CH_4 (TTM 2006a) and N_2O (TTM 2006b) emission factors used in the non-road model (INFRAS 2008).

Gas	Diesel	Gasoline		CNG
		4-stroke	2-stroke	
	mg/kWh			
CH_4	6	500	4000	10'000/1'000
N_2O	30	50	50	--

The values differ from default values (IPCC 2006, conversion factor used: 1 g/kWh = 278 kg/TJ): For CH_4 IPCC recommends 18 mg/kWh for diesel oil, 72 mg/kWh for gasoline four-stroke, 210 mg/kWh gasoline two-stroke. For N_2O IPCC gives 2 mg/kWh (diesel oil and gasoline four-stroke) and 6 mg/kWh (gasoline two-stroke).

Table A – 19 Emission and consumption factors for diesel engines (without ships and rail vehicles). PreEU-A etc. indicate emission standards.

Basic emission factors of diesel engines (g/kWh)							
power class	**PreEU-A <1996**	**PreEU-B 1996**	**EU-I 2002/2003**	**EU-II 2003/2004**	**EU-IIIA 2007/2008**	**EU-IIIB 2011/2012**	**EU-IV 2014**
Carbon monoxide (CO)							
<18 kW	6.71	6.71	2.90	2.90	2.90	2.90	2.90
18-37 kW	6.71	6.71	2.76	2.42	2.06	1.76	1.5
37-75 kW	4.68	4.68	1.87	1.63	1.39	1.19	1.01
75-130 kW	3.62	3.62	1.28	1.01	0.86	0.73	0.62
>130 kW	3.62	3.62	1.04	0.91	0.77	0.66	0.5
VOC							
<18 kW	2.28	2.28	1.60	1.00	0.59	0.59	0.59
18-37 kW	2.41	2.41	0.92	0.56	0.37	0.37	0.37
37-75 kW	1.33	1.33	0.65	0.46	0.33	0.24	0.24
75-130 kW	0.91	0.91	0.45	0.35	0.28	0.17	0.17
>130 kW	0.91	0.91	0.43	0.3	0.22	0.17	0.17
Nitrogen oxides (NO_x)							
<18 kW	10.31	8.2	5.95	5.95	5.95	5.95	5.95
18-37 kW	10.31	8.2	6.34	6.34	6.34	6.34	6.34
37-75 kW	12.4	9.87	8.95	6.56	3.90	3.39	1.87
75-130 kW	12.52	9.96	8.44	5.67	3.32	2.97	0.36
>130 kW	12.52	9.96	8.19	5.66	3.38	1.80	0.36
Fuel consumption (FC)							
<18 kW	248	248	248	248	248	248	248
18-37 kW	248	248	248	248	248	248	248
37-75 kW	248	248	248	248	248	248	248
75-130 kW	223	223	223	223	223	223	223
>130 kW	223	223	223	223	223	223	223

Table A – 20 Emission and consumption factors for gasoline four-stroke engines. PreEU-A etc. indicate emission standards. Implementation years indicated in brackets correspond to emission levels whose emission factors are based on assumptions rather than limit values

Basic emission factors of equipment with 4-stroke gasoline engines (g/kWh).							
power class	**PreEU-A <1995**	**PreEU-B 1995**	**PreEU-C 2000**	**EU-I 2004**	**EU-II 2005-2009**	**EU-III 2015**	**EU-IV 2020**
Carbon monoxide (CO)							
<66 ccm	470	470	470	467	467	400	
66-100 ccm	470	470	470	467	467	400	
100-225 ccm	470	470	470	467	467	400	
>225 ccm	470	470	470	467	467	400	
VOC							
<66 ccm	60	60	60	41	41	25	
66-100 ccm	40	40	40	32	32	25	
100-225 ccm	20	20	20	12	12	9	
>225 ccm	20	20	20	10	9	6	
Nitrogen oxides (NO_x)							
<66 ccm	1.5	2	3	4.5	4.5	4	
66-100 ccm	1.5	2	3	3.6	3.6	3	
100-225 ccm	3.5	3.5	3.5	2.8	2.8	2	
>225 ccm	3.5	3.5	3.5	2.2	1.9	2	
Fuel consumption (FC)							
<66 ccm	500	500	500	480	480	460	
66-100 ccm	480	480	480	470	470	460	
100-225 ccm	460	460	460	450	450	450	
>225 ccm	460	460	460	450	450	450	
Implementaion of emission							
<66 ccm		(1995)	(2000)	-	2005	2015	2020
66-100 ccm		(1995)	(2000)	2004	2005	2015	2020
100-225 ccm		(1995)	(2000)	2004	2009	2015	2020
>225 ccm		(1995)	(2000)	2004	2007	2015	2020

Table A – 21 Emission and consumption factors for gasoline two-stroke engines. PreEU-A etc. indicate emission standards. For Equipment which was started-up before 2004, the emission factors are not based on limit values but rather on respective assumptions (PreEU). The respective values for the implementation year is indicated in brackets; source: BUWAL 1996a.

Basic emission factors of equipment with 2-stroke gasoline engines (g/kWh)							
gas/fuel consumption	**PreEU-A <1995**	**PreEU-B 1995**	**PreEU-C 2000**	**EU-I 2004**	**EU-II 2009/2011**	**EU-III 2015**	**EU-IV 2020**
Carbon monoxide (CO)	650	640	620	600	600	500	
VOC	260	250	150	100	41	25	
Nitrogen oxides (NO_x)	1.5	2.0	3.0	4.8	4.5	4.5	
Fuel consumption (FC)	660	650	550	500	440	425	
Assumptions regarding Implementation of emission levels							
<20 ccm		(1995)	(2000)	2004	2009	2015	2020
20-50 ccm		(1995)	(2000)	2004	2009	2015	2020
>50 ccm		(1995)	(2000)	2004	2011	2015	2020

Table A – 22 Emission and consumption factors for rail vehicles with diesel engines. PreEU etc. indicate emission standards. For railed vehicles which were started-up before 2000, the emission factors are not based on limit values but rather on respective assumptions (PreEU). The respective values for the implementation year is indicated in brackets.

vehicles (g/kWh)						
power class	**PreEU <2000**	**UIC I 2000**	**UIC II 2003**	**EU IIIa 2006/2009**	**EU IIIb 2012**	**EU IV**
Carbon monoxide (CO)						
<560 kW	4	3	2.5	g 2.5	2.5	2.5
>560 kW	4	3	3	g 3.0	3	3
VOC						
<560 kW	1.6	0.8	0.6	0.4	0.17	0.17
>560 kW	1.6	0.8	0.8	0.5	0.4	0.3
Nitrogen oxides (NO_x)						
<560 kW	13	12	6	3.2	1.8	1.8
>560 kW	16	12	9.5	5.4	3.2	2
Fuel consumption (FC)						
<560 kW	223	223	223	223	223	223
>560 kW	223	223	223	223	223	223
Assumption regarding implementation of EU emission levels						
<560 kW		2000	2003	2006	2012	2020
>560 kW		2000	2003	2009	2012	2020

Table A – 23 Emission and consumption factors for ships with diesel engines. PreSAV etc. indicate emission standards. For ships which were started-up before 1995, the emission factors are not based on limit values but rather on respective assumptions (PreSAV). The respective values for the implementation year is indicated in brackets.

Basic emission factors of diesel engine ships (g/kWh)							
power class	**PreSAV <1995**	**SAV 1995**	**EU I 2003**	**EU II 2008**	**EU III-a 2009**	**EU III-b 2012**	**EU-IV 2015**
Carbon monoxide (CO)							
<18 kW	6.7	6.7	6.7	6.7	6.7	5.5	5.5
18-37 kW	6.7	6.7	6.7	6.7	6.7	5	5
37-75 kW	5.9	5.9	5.9	4.5	4.5	4.5	4.5
75-130 kW	5	5	4.5	4.5	4.5	4.5	4.5
>130 kW	5	5	4.5	4.5	4.5	3.5	3.5
VOC							
<18 kW	10	7.2	5	3	2	1	0.6
18-37 kW	10	7.2	5	3	2	1	0.4
37-75 kW	10	5.4	1.2	1.2	1.1	0.6	0.4
75-130 kW	10	4.1	1.2	0.9	0.8	0.4	0.2
130-399 kW	5	3.6	1.2	0.9	0.8	0.4	0.2
300–560 kW	5	3.2	1.2	0.9	0.8	0.4	0.2
>560 kW	5	2.8	1.2	0.9	0.8	0.4	0.2
Nitrogen oxides (NO_x)							
<18 kW	10.3	10.3	10.3	10.3	10.3	8	6
18-37 kW	10.3	10.3	10.3	10.3	10.3	8	6
37-75 kW	12.4	12.4	8.3	6.3	5.7	3.3	0.4
75-130 kW	12.5	12.5	8.3	6.3	5.7	3.3	0.4
>130 kW	12.5	12.5	8.3	6.3	5.7	2	0.4
Fuel consumption (FC)							
<18 kW	248	248	248	248	248	248	248
18-37 kW	248	248	248	248	248	248	248
37-75 kW	248	248	248	248	248	248	248
75-130 kW	223	223	223	223	223	223	223
>130 kW	223	223	223	223	223	223	223
implementation of emission							
all classes		1995	1997	2005	2010	2012	2015

Table A – 24 Emission and consumption factors for boats with diesel engines. PreSAV etc. indicate emission standards. For boats which were started-up before 1995, the emission factors are not based on limit values but rather on respective assumptions (PreSAV). The respective values for the implementation year is indicated in brackets.

Basic emission factors of diesel engine boats (g/kWh)					
power class	**PreSAV <1995**	**SAV 1995**	**EU-I 2007**	**EU II 2012**	**EU III 2015**
Carbon monoxide (CO)					
<4.4 kW	6.7	6.7	4.5	4	4
4.4-7.4 kW	6.7	6.7	4.5	4	4
7.4-37 kW	6.7	6.7	4.5	4	4
37-74 kW	5.9	5.9	4.5	4	4
74-100 kW	5	5	4.5	4	4
>100 kW	5	3.6	3.6	3.5	3.5
VOC					
<4.4 kW	10	10	2.4	1.5	1
4.4-7.4 kW	10	10	2.1	1.5	1
7.4-37 kW	10	2	1.7	1.5	1
37-74 kW	10	1.4	1.4	1.3	0.8
74-100 kW	10	1.2	1.2	1	0.5
>100 kW	5	1.2	1.2	1	0.5
Nitrogen oxides (NO_x)					
<4.4 kW	13	11	8.8	6	4
4.4-7.4 kW	13	11	8.8	6	4
7.4-37 kW	13	11	8.8	6	4
37-74 kW	13	11	8.8	6	3
74-100 kW	13	11	8.8	6	3
>100 kW	13	11	8.8	6	2
Fuel consumption (FC)					
<4.4 kW	400	400	400	400	400
4.4-7.4 kW	400	400	400	400	400
7.4-37 kW	400	380	380	380	380
37-74 kW	380	350	350	350	350
74-100 kW	400	330	330	330	330
>100 kW	300	300	300	300	300
Implementaion of emission					
all classes		1995	2007	2012	2015

Table A – 25 Emission and consumption factors for boats with gasoline engines. PreSAV etc. indicate emission standards. For boats which were started-up before 1997, the emission factors are not based on limit values but rather on respective assumptions (PreSAV). The respective values for the implementation year is indicated in brackets.

Basic emission factors of gasoline engine boats (g/kWh)						
power class	**2-stroke gasoline engine**			**4-stroke gasoline engine**		
	PreSAV <1995	**SAV 1995**	**SAV/EU 2007**	**PreSAV <1995**	**SAV 2007**	**EU 2007**
Carbon monoxide (CO)						
<4.4 kW	645	315	315	350	315	315
4.4-7.4 kW	645	200	225	350	200	225
7.4-37 kW	645	100	162	350	100	162
37-74 kW	645	65	144	350	65	144
74-100 kW	645	55	141	350	55	141
>100 kW	645	45	139	350	45	139
VOC						
<4.4 kW	260	22	25	25	22	25
4.4-7.4 kW	260	12	13	20	12	13
7.4-37 kW	260	6	8	20	6	8
37-74 kW	260	4	6	20	4	6
74-100 kW	260	3.3	5	20	3.3	5
>100 kW	260	2.1	5	20	2.1	5
Nitrogen oxides (NO_x)						
<4.4 kW	15	13	13	3.5	13	13
4.4-7.4 kW	15	9.3	9.3	3.5	9.3	9.3
7.4-37 kW	15	9.3	9.3	3.5	9.3	9.3
37-74 kW	15	9.3	9.3	3.5	9.3	9.3
74-100 kW	15	9.3	9.3	3.5	9.3	9.3
>100 kW	15	9.6	9.6	3.5	9.6	9.6
Fuel consumption (FC)						
<4.4 kW	700	400	400	400	400	400
4.4-7.4 kW	700	400	400	400	400	400
7.4-37 kW	650	380	380	380	380	380
37-74 kW	650	380	380	380	380	380
74-100 kW	650	380	380	380	380	380
>100 kW	650	380	380	380	380	380
implementation of EU						
all classes	<1995	1995	2007	<1995	1995	2007

Table A – 26 Emission and consumption factors (FC) for ships with steam engines (gas oil). steam 1 etc. indicate emission standards.

Basic emission factors of steam (gas oil) engine ships (g/kWh)							
pollutant	**steam 1 <1950**	**steam 2 1950**	**steam 3 1980**	**steam 4 1990**	**steam 5 1995**	**steam 6 2005**	**steam 7 2005**
CO	0.3	0.3	0.3	0.09	0.09	0.09	0.09
HC	0.45	0.45	0.45	0.33	0.33	0.33	0.33
NO_x	2.34	2.34	2.34	1.77	1.56	1.26	1.03
PM	0.033	0.024	0.015	0.009	0.006	0.006	0.006
FC	1406	1012	787	703	703	703	703
implementaion of EU							
all classes	1950	1950	1980	1990	1995	2000	2005

Activity data non-road vehicles

The activity data are described in detail in INFRAS (2008). Aggregated numbers are shown in the following tables.

Table A – 27 Number of vehicles per non-road family (INFRAS 2008)

Family	1990	1995	2000	2005	2010	2015	2020
	no. of vehicles						
Construction	56'070	52'443	47'995	47'354	48'162	48'770	48'812
Industry	13'947	18'372	22'748	22'748	23'739	24'499	25'081
Agriculture	324'567	324'047	337'869	339'948	359'496	372'900	381'350
Forestry	13'844	13'357	13'055	12'749	12'548	12'144	11'588
Garden/Hobby	659'828	719'118	779'052	763'881	786'481	800'506	807'955
Navigation	93'395	89'042	82'674	82'647	86'790	90'134	92'860
Railway	1'300	1'305	1'255	1'255	1'318	1'370	1'412
Military	1'340	1'340	1'340	1'340	1'408	1'462	1'507
Sum	**1'164'291**	**1'219'024**	**1'285'988**	**1'271'922**	**1'319'942**	**1'301'402**	**1'275'696**

Table A – 28 Operating hours per vehicle per year and (Table A- 1million) operating hours per non-road family (INFRAS 2008).

Family	1990	1995	2000	2005	2010	2015	2020
	operating hours per veh. per year						
Construction	299	353	383	386	387	388	388
Industry	628	648	660	660	660	659	659
Agriculture	119	118	112	108	104	100	98
Forestry	199	201	203	202	202	201	200
Garden/Hobby	22	25	27	27	27	28	28
Navigation	40	39	40	40	40	40	40
Railway	612	627	616	616	616	616	616
Military	51	53	54	52	49	47	45

Family	1990	1995	2000	2005	2010	2015	2020
	mio. of operating hours						
Construction	16.75	18.52	18.38	18.26	18.65	18.95	18.95
Industry	8.76	11.90	15.01	15.01	15.66	16.16	16.53
Agriculture	38.77	38.21	37.68	36.57	37.26	37.45	37.26
Forestry	2.76	2.68	2.64	2.57	2.53	2.44	2.32
Garden/Hobby	14.42	17.71	21.09	20.78	21.52	22.04	22.40
Navigation	3.72	3.46	3.34	3.33	3.49	3.61	3.71
Railway	0.80	0.82	0.77	0.77	0.81	0.84	0.87
Military	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Sum	**86.04**	**93.37**	**98.99**	**97.36**	**100.00**	**101.56**	**102.11**

A3.1.5 Sulphur Dioxide (SO_2)

Table A – 29 Sulphur content and SO_2 emission factors.

year	maximum legal limit of sulphur content					
	Diesel oil ppm	Gasoline ppm	Gas oil ppm	Natural gas ppm	Res. fuel oil %	Coal %
1990	1400	200	2000	190	1.0	1.0
1991	1300	200	2000	190	1.0	1.0
1992	1200	200	2000	190	1.0	1.0
1993	1000	200	2000	190	1.0	1.0
1994	500	200	2000	190	1.0	1.0
2000	350	150	2000	190	1.0	1.0
2005	50	50	2000	190	1.0	1.0
2008	50	50	1000	190	1.0	1.0
2009	10	50	1000	190	1.0	1.0
2010	10	10	1000	190	1.0	1.0
2011	10	10	1000	190	1.0	1.0
2012	10	10	1000	190	1.0	1.0
2013	10	10	1000	190	1.0	1.0

year	Effective sulphur content						
	Diesel oil ppm	Gasoline ppm	Gas oil ppm	Natural gas ppm	Res. fuel oil %	Lignite %	Kerosene ppm
1990	1400	200	1600	11.6	0.97	0.004	551
1991	1300	200	1300	11.6	0.89	0.004	540
1992	1200	200	1200	11.6	0.86	0.004	543
1993	1000	200	1000	11.6	0.87	0.004	543
1994	434	200	1350	11.6	0.77	0.004	541
1995	341	200	1170	11.6	0.78	0.004	544
1996	372	200	1160	11.6	0.78	0.004	542
1997	353	200	1250	11.6	0.70	0.004	538
1998	402	200	926	11.6	0.83	0.004	536
1999	443	200	650	11.6	0.62	0.004	538
2000	272	142	680	11.6	0.66	0.004	535
2001	250	121	830	11.6	0.82	0.004	522
2002	235	101	798	11.6	0.82	0.004	507
2003	200	81	700	11.6	0.79	0.004	500
2004	10	8.0	700	11.6	0.76	0.004	498
2005	10	8.0	799	11.6	0.78	0.004	491
2006	10	8.0	699	11.6	0.74	0.004	460
2007	10	8.0	630	11.6	0.71	0.004	465
2008	10	8.0	641	11.6	0.67	0.004	461
2009	7.2	5.2	603	11.6	0.64	0.004	460
2010	9	6	548	11.6	0.60	0.004	460
2011	5	8	116	11.6	0.60	0.004	462
2012	7	6	617	11.6	0.60	0.004	464
2013	8	5	253	11.6	0.60	0.004	467

year	Effective SO_2 emission factor							
	Diesel oil	Gasoline	Gas oil	Natural gas	Res. fuel oil	Lignite	Bituminous coal	Kerosene (average)
	kg/TJ							
1990	65.4	9.4	75.1	0.50	473	500	500/350	26
1991	60.8	9.4	61.0	0.50	432	500	500/350	25
1992	56.1	9.5	56.3	0.50	417	500	500/350	25
1993	46.8	9.5	46.9	0.50	422	500	500/350	25
1994	20.3	9.5	63.4	0.50	374	500	500/350	25
1995	15.9	9.3	54.9	0.50	377	500	500/350	25
1996	17.3	9.2	54.5	0.50	379	500	500/350	25
1997	16.4	9.3	58.7	0.50	340	500	500/350	25
1998	18.7	9.3	43.5	0.50	403	500	500/350	25
1999	20.6	9.3	30.5	0.50	301	500	500/350	25
2000	12.6	6.6	31.9	0.50	320	500	500/350	25
2001	11.6	5.7	39.0	0.50	398	500	500/350	24
2002	10.9	4.7	37.5	0.50	398	500	500/350	24
2003	9.3	3.7	32.9	0.50	383	500	500/350	23
2004	0.5	0.4	32.9	0.50	369	500	500/350	23
2005	0.5	0.4	37.5	0.50	379	500	500/350	23
2006	0.5	0.4	32.8	0.50	361	500	500/350	21
2007	0.5	0.4	29.6	0.50	344	500	500/350	22
2008	0.5	0.4	30.1	0.50	326	500	500/350	21
2009	0.5	0.4	25.3	0.50	309	500	500/350	21
2010	0.5	0.4	25.7	0.50	291	500	500/350	21
2011	0.5	0.4	24.1	0.50	291	500	500/350	21
2012	0.5	0.4	22.4	0.50	291	500	500/350	22
2013	0.5	0.4	20.8	0.50	291	500	500/350	22

Explanation to Table A - 29

- For liquid and solid fuels the SO_2 emission factors are determined by the sulphur content. The upmost lines in Table A - 29 "maximum legal limit on sulphur content" show the maximum values as defined in the Federal Ordinance on Air Pollution Control OAPC (Swiss Confederation 1985).
- The lines in the middle part of Table A - 29 contain the effective sulphur contents. They are based on measurements: Summary and annual reports of the Swiss Petroleum Association (EV), reports by the Federal Administration of Customs (OZD) since 2000.
- The lines at the bottom part of Table A - 29 give the emission factors in kg/TJ. They are calculated from the sulphur content S, the net calorific value NCV and the quotient of the molar masses of S and SO_2

$$EF_{SO2} = \frac{M_{SO2}}{M_S} \cdot \frac{S}{NCV} = 2 \cdot \frac{S}{NCV}$$

- Coal: Note that the legal limit of sulphur content depends on the size of the heat capacity of the combustion system. The value shown in the table above (1%, 350 kg/TJ SO_2) holds for heat capacity below 1 MW; see OAPC Annex 4, §513 (Swiss Confederation 1985). For larger capacities the value is 3% (OAPC Annex 5, §2, Swiss Confederation 1985). For industrial combustion plants, the limit for the exhaust emissions actually sets the corresponding maximum sulphur content to 1.4% (500 kg/TJ).
- Residual fuel oil: OAPC Annex 5, §11, lit.2 sets 2.8% for the legal limit. Simultaneously, OAPC dispenses from emission control measurements if residual fuel oil is used with sulphur content of maximum 1% (see OAPC Annex 3, §421, lit. 2, Swiss Confederation 1985), which holds for most combustion plants.

A3.2 Industrial Processes (Illustrative example of mobile air conditioning)

The use of HFC as substitutes of ODS in 2F1 refrigeration and air conditioning is the main factor for the increase of HFC emission 1990 to 2013. Refrigerants contained in installed equipment lead to a considerable stock with annual losses depending from equipment type between 0.5% to 15% (see Table 4-38). Emissions are calculated for the production, operation, service and disposal of equipment. The following illustrative example shows the calculations for the example of mobile air conditioning (HFC-134a use as refrigerant). The example is calculated bottom up based on vehicle statistics and informations on air conditioning equipment. There is no production of air conditioning equipment for cars in Switzerland, equipment is imported already charged.

Table A – 30 Applied model parameters and assumption for mobile air conditioning of cars

Initial charge in kg HFC per unit AC	1994	0.81
	2002	0.7
	Other years inter-/extrapolated	
All units are imported with refrigerants charged		
Emission factor 1995	Annual loss	8.5%
	Share recharged regularly	6.0%
	Share not recharged	2.5%
Charge at end of life		58.0%
Disposal emissions	Up to 1990	100.0%
	From 2000 onwards	50.0%
Average export rate of second hand cars		50.0%
Reuse by Garages of recovered refrigerant (estimate value)		80.0%
Car servicing emission factor (car service every 4 years)		10.0%
Product lifetime		15
Market growth rate		0.5%

Table A – 31 Bottom up calculations to identify number of air conditioning equipment and amount of HFC-134a

Year	New registered vehicles	Vehicles in use	Disposed vehicles	New equipment: number of air conditioning units with HFC-134a in new registered cars			Equipment stock: Number of air conditioning units with HFC-134a in use		Equipment disposal	Initial equipment charge
	(Statistics)	(Statistics)	(Calculated)	Portion of vehicles with AC [%]	HFC-134a as refrigerant [%]	AC units with HFC-134	Portion of vehicles with HFC-134a [%]	Units with HFC-134	Units AC with HFC-134a	kg HFC/ unit
1989	335'094	2'895'842		5	0	0	0	0	0	0.85
1990	327'456	2'985'399	237'899	6	0	0	0	0	0	0.84
1991	314'824	3'057'800	242'423	7	10	2'204	0	2'204	0	0.83
1992	296'009	3'091'230	262'579	9	30	7'992	0	10'196	0	0.83
1993	262'814	3'109'524	244'520	14	66	24'284	1	34'480	0	0.82
1994	270'009	3'165'043	214'490	19	90	46'172	3	80'652	0	0.81
1995	272'897	3'229'169	208'771	24	100	65'495	5	146'147	0	0.78
1996	269'529	3'268'073	230'625	38	100	102'421	8	248'568	0	0.77
1997	272'441	3'323'421	217'093	52	100	141'669	12	390'237	0	0.76
1998	297'336	3'383'275	237'482	68	100	202'188	18	592'426	0	0.75
1999	317'985	3'467'275	233'985	75	100	238'489	24	830'914	0	0.73
2000	315'398	3'545'247	237'426	77	100	242'856	30	1'073'771	0	0.72
2001	317'126	3'629'713	232'660	85	100	269'557	37	1'343'328	0	0.71
2002	295'109	3'704'822	220'000	87	100	256'745	43	1'600'073	0	0.70
2003	271'541	3'754'000	222'363	89	100	241'671	49	1'841'744	0	0.69
2004	269'211	3'811'351	211'860	91	100	244'982	55	2'086'726	0	0.68
2005	259'426	3'863'807	206'970	92	100	238'672	60	2'325'398	0	0.66
2006	269'421	3'899'917	233'311	96	100	258'644	66	2'582'409	1'633	0.65
2007	284'674	3'955'787	228'804	96	100	273'287	72	2'849'519	6'178	0.64
2008	288'525	4'030'965	213'347	96	100	276'984	77	3'106'789	19'713	0.63
2009	266'018	4'051'569	245'414	96	100	255'377	82	3'320'201	41'966	0.61
2010	294'239	4'119'370	226'438	96	100	282'469	86	3'548'325	54'345	0.60
2011	327'896	4'209'300	237'966	96	100	314'780	90	3'772'678	90'427	0.59
2012	328'139	4'254'725	282'714	96	100	315'013	93	3'940'680	147'011	0.58
2013	310'154	4'320'885	243'994	96	92	273'928	94	4'048'692	165'916	0.56

Table A – 32 Results and structure of emission calculations of HFC-134a from mobile air conditioning of cars for the inventories 1990 to 2013. Changes of parameters were found in a request carried out for the inventory 2013 (further reduction of charge since last request 2002).

	Activity			Emissions				Recharge	
HFC-134a	Input with vehicles [t]	Stock [t]	Disposed [t]	Stock incl. Recharge [t]	Disposal [t]	Recharge [t]	Total [t]	import in bulk [t]	recovered and reused [t]
1990	0	0	0	0	0	0	0	0	0
1991	2	2	0	0	0	0	0	0.1	0.0
1992	7	8	0	0	0	0	0	0.3	0.0
1993	20	28	0	2	0	0	2	1.1	0.0
1994	37	65	0	4	0	0	4	2.8	0.0
1995	51	115	0	8	0	0	8	5.4	0.0
1996	79	191	0	14	0	1	14	9.2	0.0
1997	107	294	0	23	0	2	23	14.6	0.0
1998	151	437	0	35	0	4	35	21.9	0.0
1999	175	599	0	49	0	5	49	31.1	0.0
2000	175	756	0	65	0	8	65	40.6	0.0
2001	191	922	0	82	0	11	82	50.4	0.0
2002	180	1'070	0	100	0	15	100	59.8	0.0
2003	166	1'197	0	114	0	17	114	68.0	0.0
2004	165	1'316	0	124	0	18	124	75.4	0.0
2005	158	1'425	0	136	0	19	136	82.2	0.0
2006	168	1'540	1	144	0	18	144	89.0	0.2
2007	174	1'658	3	153	1	17	153	96.0	0.6
2008	173	1'772	9	162	2	17	165	102.9	1.9
2009	156	1'860	20	170	5	16	175	108.9	4.0
2010	169	1'948	25	179	6	17	185	114.2	5.0
2011	185	2'044	41	187	10	17	197	119.8	8.1
2012	181	2'117	65	194	16	17	210	124.8	13.0
2013	178	2'137	72	196	18	16	214	127.6	14.4

A3.3 Agriculture

Additional data for estimating CH_4 emission from Enteric fermentation

Table A – 33 Data for estimating enteric fermentation emission factors for cattle (Table according to outline in IPCC 1997c, p 4.31 – 4.33).

Type	Age[a]	Weight[a] kg	Weight Gain[a] kg/day	Feeding Situation / Further Specificationa	Milkb kg/day	Work hrs/day	Pregnant[a] %	Digestibility of Feed %[d]	Y_m [d] %	Em. Factor kg/head/year[e]
Mature Dairy Cattle	NA	650	0		16.1-22.6 [c]	0	305 days of lactation	72	6.90	135.69
Other Mature Cattle	NA	550	0		8.2	0		60	6.50	87.43
Fattening Calves	0-98 days	60-200	1.43	Rations of unskimmed milk and supplement feed when life weight exceeds 100 kg. Rations are apportioned on two servings per day.	0	0	0	65	0.00	0.00
Pre-Weaned Calves	0-10 month	60-325	1	"Natura beef" production, milk from mother cow and additional feed.	0	0	0	65	6.50	19.53
Breeding Calves	0-4 month	50-120	0.8	Feeding plan for a dismission with 14 to 15 weeks. Milk, feed concentrate (100kg in total), hay (80 kg in total).	0	0	0	65	6.50	28.80
Breeding Cattle (4-12 months)	4-12 month	120-300	0.8	Premature race (Milk-race)	0	0	0	60	6.50	
Breeding Cattle (> 1 year)	12-28/30 month	300-600	0.8	Premature race (Milk-race)	0	0	0	60	6.50	55.03
Fattening Calves (0-4 months)	0-4 month	70-175	0.86	Diet based on milk or milk-powder and feed concentrate, hay and/or silage	0	0	0	65	6.50	44.18
Fattening Cattle (4-12 months)	4-12 month	175-550	1.3	Feeding recommendations for fattening steers, concentrate based	0	0	0	60	6.50	

a Data source: RAP 1999 and calculations according to Soliva 2006.

b Milk production in kg/day is calculated by dividing the average annual milk production per head by 305 days (lactation period).

c data source: Swiss farmers union (SBV 2014).

d data source: IPCC 2006 and Zeitz et al. 2012.

e For better comparability emission factors of young cattle were converted to kg/head/year although the time span of most of the individual categories is less than 365 days.

Table A – 34 Gross energy intake of Swiss livestock 1990-2013.

Gross Energy Intake		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
		MJ/head/day																							
Cattle																									
Mature Dairy Cattle		259.3	261.6	261.9	265.0	264.7	267.4	266.4	270.4	274.2	277.4	280.1	281.8	284.5	287.7	291.5	291.6	292.2	295.2	297.2	299.8	300.7	301.4	301.2	299.8
Other Mature Cattle		205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1
Growing Cattle (weighted average)		93.6	93.5	93.6	93.4	94.0	94.3	93.7	94.1	93.1	92.1	93.4	92.3	91.9	91.6	91.3	90.8	90.9	90.7	90.8	90.4	90.4	90.1	89.8	89.7
	Fattening Calves	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*
	Pre-Weaned Calves	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*
	Breeding Calves	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*	*26.9*
	Breeding Cattle (4-12 months)	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*	*89.2*
	Breeding Cattle (> 1 year)	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*
	Fattening Calves (0-4 months)	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*	*55.6*
	Fattening Cattle (4-12 months)	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*	*124.6*
Sheep		21.2	21.7	22.2	22.4	23.8	24.0	22.0	22.1	21.5	22.9	22.4	22.9	22.8	22.7	23.3	22.8	22.6	22.2	22.0	22.7	22.6	22.6	22.5	22.9
Swine		28.3	28.9	29.0	29.1	28.5	31.9	29.8	29.9	27.9	29.0	28.0	27.7	27.1	27.0	27.2	26.6	26.3	26.9	26.7	27.0	27.2	26.9	27.0	28.7
Buffalo (weighted average)		NA	NA	134.7	138.2	137.5	136.6	137.0	136.5	137.0	130.6	146.9	137.5	140.8	137.2	140.0	140.6	138.9	130.4	129.1	134.8	136.9	139.8	135.9	136.0
	Bisons < 3 years	*91.0*	*91.0*	*91.0*	*91.0*	*91.0*	*91.0*	*91.0*	*91.0*	*91.0*	*91.0*	*91.0*	*91.0*	*91.0*	*91.0*	*91.0*	*91.0*	*91.0*	*91.0*	*91.0*	*91.0*	*91.0*	*91.0*	*91.0*	*91.0*
	Bisons > 3 years	*197.1*	*197.1*	*197.1*	*197.1*	*197.1*	*197.1*	*197.1*	*197.1*	*197.1*	*197.1*	*197.1*	*197.1*	*197.1*	*197.1*	*197.1*	*197.1*	*197.1*	*197.1*	*197.1*	*197.1*	*197.1*	*197.1*	*197.1*	*197.1*
Camels (weighted average)		NA	NA	NA	NA	NA	NA	37.9	37.9	37.9	34.6	34.8	32.2	33.0	34.0	32.8	31.7	31.7	31.7	31.6	31.5	31.0	31.4	31.6	31.9
	Llamas < 2 years	*24.8*	*24.8*	*24.8*	*24.8*	*24.8*	*24.8*	*24.8*	*24.8*	*24.8*	*24.8*	*24.8*	*24.8*	*24.8*	*24.8*	*24.8*	*24.8*	*24.8*	*24.8*	*24.8*	*24.8*	*24.8*	*24.8*	*24.8*	*24.8*
	Llamas > 2 years	*43.0*	*43.0*	*43.0*	*43.0*	*43.0*	*43.0*	*43.0*	*43.0*	*43.0*	*43.0*	*43.0*	*43.0*	*43.0*	*43.0*	*43.0*	*43.0*	*43.0*	*43.0*	*43.0*	*43.0*	*43.0*	*43.0*	*43.0*	*43.0*
	Alpacas < 2 years	*15.2*	*15.2*	*15.2*	*15.2*	*15.2*	*15.2*	*15.2*	*15.2*	*15.2*	*15.2*	*15.2*	*15.2*	*15.2*	*15.2*	*15.2*	*15.2*	*15.2*	*15.2*	*15.2*	*15.2*	*15.2*	*15.2*	*15.2*	*15.2*
	Alpacas > 2 years	*27.8*	*27.8*	*27.8*	*27.8*	*27.8*	*27.8*	*27.8*	*27.8*	*27.8*	*27.8*	*27.8*	*27.8*	*27.8*	*27.8*	*27.8*	*27.8*	*27.8*	*27.8*	*27.8*	*27.8*	*27.8*	*27.8*	*27.8*	*27.8*
Deer (weighted average)		50.5	51.6	53.6	54.5	55.0	55.3	59.7	55.4	54.8	55.5	56.4	55.8	56.7	55.2	55.6	55.4	55.8	55.9	56.5	56.8	56.5	56.7	57.0	58.1
	Fallow Deer [1]	*50.5*	*50.5*	*50.5*	*50.5*	*50.5*	*50.5*	*50.5*	*50.5*	*50.5*	*50.5*	*50.5*	*50.5*	*50.5*	*50.5*	*50.5*	*50.5*	*50.5*	*50.5*	*50.5*	*50.5*	*50.5*	*50.5*	*50.5*	*50.5*
	Red Deer [1]	*101.1*	*101.1*	*101.1*	*101.1*	*101.1*	*101.1*	*101.1*	*101.1*	*101.1*	*101.1*	*101.1*	*101.1*	*101.1*	*101.1*	*101.1*	*101.1*	*101.1*	*101.1*	*101.1*	*101.1*	*101.1*	*101.1*	*101.1*	*101.1*
Goats		25.0	24.6	25.0	25.4	25.5	27.9	25.3	25.6	26.9	25.8	25.7	26.0	25.2	25.4	25.2	25.4	25.3	25.0	25.0	25.3	25.1	25.6	25.7	26.1
Horses (weighted average)		107.3	107.3	107.3	107.3	107.1	106.9	107.1	107.3	107.3	107.2	107.4	107.5	107.6	107.6	107.6	107.7	107.7	107.7	107.7	107.8	107.9	107.9	107.9	108.0
	Horses <3 years	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*
	Horses >3 years	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*
Mules and Asses (weighted average)		39.2	39.2	39.2	39.2	39.5	39.7	39.7	39.8	39.6	39.8	39.5	39.6	39.6	39.6	39.5	39.4	39.5	39.3	39.2	40.0	40.2	39.9	39.9	39.6
	Mules	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*
	Asses	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*
Poultry [2]		1.5	1.5	1.6	1.3	1.4	1.3	1.4	1.4	1.3	1.4	1.4	1.4	1.3	1.3	1.3	1.2	1.2	1.3	1.3	1.3	1.2	1.2	1.2	1.2
Rabbits		1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Livestock NCAC (weighted average)		95.6	95.6	95.6	95.6	96.1	83.4	43.2	40.1	38.6	38.6	37.7	36.5	35.7	34.6	34.6	33.3	33.2	32.9	31.7	32.3	32.9	31.7	31.0	31.5
	Sheep Non-Agr.	*21.2*	*21.7*	*22.2*	*22.4*	*23.8*	*24.0*	*22.0*	*22.1*	*21.5*	*22.9*	*22.4*	*22.9*	*22.8*	*22.7*	*23.3*	*22.8*	*22.6*	*22.2*	*22.0*	*22.7*	*22.6*	*22.6*	*22.5*	*22.9*
	Goats Non-Agr.	*25.0*	*24.6*	*25.0*	*25.4*	*25.5*	*27.9*	*25.3*	*25.6*	*26.9*	*25.8*	*25.7*	*26.0*	*25.2*	*25.4*	*25.2*	*25.4*	*25.3*	*25.0*	*25.0*	*25.3*	*25.1*	*25.6*	*25.7*	*26.1*
	Horses <3 years Non-Agr.	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*
	Horses >3 years Non-Agr.	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*
	Mules Non-Agr.	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*	*86.0*
	Asses Non-Agr.	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*	*37.9*

1) Deer: Gross energy intake per animal place (mother with offspring)

2) Poultry data is not Gross Energy intake (GE) but Metabolizable Energy intake (ME)

Table A – 35 Livestock population 1990-2013.

Population Size	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
	1000 head																							
Cattle	1855.2	1828.9	1782.6	1745.1	1755.4	1748.3	1747.1	1672.9	1640.9	1608.7	1588.0	1611.4	1593.7	1570.2	1544.5	1554.7	1566.9	1571.8	1604.3	1597.5	1591.2	1577.4	1564.6	1557.5
Mature Dairy Cattle	783.1	780.5	763.5	744.5	749.7	739.6	736.0	711.6	701.3	683.5	669.4	669.4	657.9	638.3	621.0	620.7	618.1	614.8	628.5	599.4	589.0	589.2	591.2	586.6
Other Mature Cattle	12.0	14.0	17.0	18.0	20.0	23.0	28.0	32.0	36.0	41.2	44.9	50.6	58.1	65.1	70.0	78.5	87.3	93.5	98.4	108.4	111.3	110.7	114.4	116.9
Growing Cattle	1060.1	1034.4	1002.1	982.6	985.7	985.6	983.0	929.3	903.5	884.0	873.7	891.3	877.7	866.7	853.6	855.5	861.5	863.4	877.4	889.7	890.9	877.5	859.0	854.0
Fattening Calves	*112.3*	*111.4*	*109.5*	*111.1*	*101.4*	*101.7*	*112.0*	*106.0*	*108.1*	*116.4*	*103.3*	*114.7*	*114.4*	*113.9*	*111.3*	*105.6*	*101.2*	*100.5*	*95.0*	*100.5*	*99.4*	*100.5*	*98.6*	*97.0*
Pre-Weaned Calves	*9.6*	*11.2*	*13.6*	*14.4*	*16.0*	*18.4*	*22.4*	*25.6*	*28.8*	*33.2*	*35.7*	*40.4*	*46.9*	*52.3*	*56.6*	*62.5*	*67.3*	*72.2*	*76.1*	*85.8*	*88.1*	*87.6*	*90.6*	*92.5*
Breeding Cattle 1st Year	*346.4*	*336.7*	*324.0*	*308.2*	*306.2*	*294.7*	*286.1*	*260.1*	*253.5*	*218.7*	*236.0*	*238.1*	*229.5*	*219.8*	*214.7*	*222.0*	*223.3*	*223.3*	*232.4*	*225.7*	*226.4*	*220.7*	*212.3*	*210.3*
Breeding Cattle 2nd Year	*253.3*	*251.9*	*250.5*	*238.7*	*237.2*	*238.6*	*243.0*	*232.9*	*217.4*	*187.5*	*221.9*	*219.3*	*219.1*	*212.7*	*205.4*	*204.7*	*210.2*	*210.5*	*212.7*	*212.2*	*212.8*	*207.5*	*199.5*	*197.7*
Breeding Cattle 3rd Year	*150.7*	*148.4*	*146.7*	*142.3*	*141.3*	*139.4*	*139.9*	*139.3*	*132.7*	*117.9*	*129.8*	*130.4*	*126.0*	*124.0*	*120.9*	*113.3*	*110.1*	*109.1*	*109.6*	*118.8*	*119.2*	*116.2*	*111.8*	*110.7*
Fattening Cattle	*187.8*	*174.8*	*157.8*	*168.0*	*183.5*	*192.9*	*179.6*	*165.4*	*163.1*	*210.2*	*147.1*	*148.5*	*141.7*	*144.1*	*144.7*	*147.5*	*149.3*	*148.0*	*151.6*	*146.6*	*145.1*	*145.0*	*146.2*	*145.7*
Sheep	395.2	409.4	414.7	424.0	405.4	386.7	418.6	420.4	422.3	423.5	420.7	420.0	429.5	444.8	440.5	446.4	447.5	443.6	446.2	431.9	434.1	424.0	417.3	409.5
Fattening Sheep	*190.6*	*200.8*	*201.0*	*211.1*	*201.2*	*191.4*	*207.6*	*208.0*	*208.7*	*221.7*	*216.6*	*216.6*	*219.9*	*228.6*	*227.5*	*229.4*	*230.6*	*230.0*	*229.4*	*227.3*	*228.2*	*221.8*	*219.3*	*216.2*
Milksheep	*4.3*	*4.0*	*3.8*	*3.5*	*3.3*	*3.0*	*2.8*	*3.1*	*4.4*	*5.8*	*6.7*	*7.0*	*7.2*	*8.0*	*8.1*	*8.9*	*9.5*	*10.2*	*10.7*	*11.7*	*12.4*	*12.4*	*12.8*	*13.3*
Swine	1787.0	1722.6	1705.7	1691.8	1568.7	1445.6	1379.4	1394.9	1487.0	1453.3	1498.2	1547.7	1556.7	1528.9	1537.5	1609.5	1634.8	1573.1	1540.1	1557.2	1589.0	1578.7	1544.0	1484.7
Piglets	*299.4*	*282.5*	*290.8*	*299.6*	*287.2*	*274.8*	*240.9*	*252.2*	*261.8*	*281.0*	*296.6*	*318.8*	*326.6*	*322.8*	*327.8*	*337.6*	*366.5*	*344.8*	*336.1*	*338.4*	*350.9*	*352.7*	*344.7*	*333.3*
Fattening Pig over 25 kg	*1024.6*	*989.6*	*972.8*	*943.0*	*855.5*	*767.9*	*778.7*	*779.6*	*837.4*	*734.4*	*750.9*	*762.5*	*767.9*	*751.7*	*753.2*	*796.7*	*786.1*	*766.9*	*763.2*	*779.5*	*788.1*	*787.2*	*775.5*	*748.1*
Dry Sows	*129.3*	*126.0*	*124.9*	*125.3*	*117.1*	*108.9*	*98.8*	*104.3*	*110.9*	*101.2*	*104.8*	*108.0*	*108.6*	*105.3*	*107.9*	*112.7*	*115.2*	*105.7*	*105.4*	*104.7*	*106.1*	*103.4*	*97.4*	*95.8*
Nursing Sows	*37.4*	*36.8*	*36.8*	*37.3*	*35.1*	*33.0*	*30.2*	*29.9*	*31.4*	*35.0*	*36.7*	*37.5*	*36.5*	*35.8*	*35.3*	*36.0*	*36.5*	*34.9*	*32.6*	*33.1*	*33.5*	*32.3*	*31.0*	*29.4*
Boars	*8.4*	*8.1*	*8.0*	*8.2*	*7.7*	*7.1*	*6.3*	*6.4*	*6.4*	*6.2*	*6.2*	*6.1*	*5.8*	*5.3*	*5.2*	*5.1*	*4.9*	*4.2*	*4.0*	*3.8*	*3.7*	*3.3*	*3.0*	*3.2*
Buffalo	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.3	0.4	0.5	0.6	0.5	0.5	0.5	0.5
Bisons < 3 years	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.1*	*0.1*	*0.0*	*0.1*	*0.2*	*0.1*	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*
Bisons > 3 years	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.1*	*0.0*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*
Camels	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.4	1.0	1.0	1.6	1.6	1.7	2.2	3.1	3.3	3.9	4.4	4.7	6.1	6.0	5.8	5.9
Llamas < 2 years	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.1*	*0.1*	*0.1*	*0.2*	*0.2*	*0.3*	*0.3*	*0.3*	*0.4*	*0.5*	*0.5*	*0.6*	*0.7*	*0.8*	*0.8*	*0.8*	*0.7*	*0.7*
Llamas > 2 years	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.2*	*0.2*	*0.3*	*0.5*	*0.5*	*0.7*	*0.7*	*0.9*	*1.0*	*1.1*	*1.3*	*1.5*	*1.8*	*1.9*	*2.1*	*2.2*	*2.3*	*2.4*
Alpacas < 2 years	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.2*	*0.1*	*0.1*	*0.2*	*0.3*	*0.4*	*0.5*	*0.6*	*0.7*	*0.8*	*0.7*	*0.8*	*0.8*
Alpacas > 2 years	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.2*	*0.2*	*0.5*	*0.5*	*0.4*	*0.6*	*1.2*	*1.1*	*1.2*	*1.3*	*1.4*	*2.3*	*2.3*	*2.0*	*2.1*
Deer	0.2	0.4	0.7	0.9	1.2	1.4	1.9	1.9	2.2	2.6	2.8	2.9	3.1	3.2	3.5	3.8	4.2	4.4	4.8	5.1	5.5	5.7	5.7	5.7
Fallow Deer	*0.2*	*0.4*	*0.6*	*0.8*	*1.1*	*1.3*	*1.6*	*1.8*	*2.0*	*2.4*	*2.5*	*2.6*	*2.7*	*2.9*	*3.2*	*3.5*	*3.7*	*4.0*	*4.3*	*4.4*	*4.9*	*5.0*	*5.0*	*4.8*
Red Deer	*0.0*	*0.0*	*0.0*	*0.1*	*0.1*	*0.1*	*0.4*	*0.2*	*0.2*	*0.3*	*0.3*	*0.3*	*0.4*	*0.3*	*0.4*	*0.4*	*0.4*	*0.5*	*0.6*	*0.6*	*0.7*	*0.7*	*0.7*	*0.8*
Goats	68.3	65.2	58.2	56.7	54.9	53.2	56.8	58.0	60.1	61.6	62.5	63.0	66.0	67.4	70.6	74.0	76.3	79.1	81.4	81.2	82.8	83.0	84.7	84.5
Goat Places	*44.8*	*43.1*	*38.4*	*37.3*	*35.9*	*34.6*	*37.1*	*37.7*	*39.8*	*40.8*	*41.4*	*42.1*	*43.0*	*44.9*	*46.2*	*48.5*	*50.5*	*51.9*	*53.4*	*54.3*	*54.7*	*55.9*	*57.4*	*57.4*
Horses	28.2	30.2	32.3	34.5	37.9	41.4	43.0	45.8	46.3	48.5	50.3	50.1	51.2	52.7	53.7	55.1	56.4	57.7	59.0	60.2	62.1	57.2	58.0	57.2
Horses <3 years	*6.1*	*6.5*	*7.0*	*7.4*	*9.2*	*11.0*	*10.7*	*10.0*	*10.0*	*11.0*	*10.1*	*9.7*	*9.5*	*9.4*	*9.4*	*9.4*	*9.5*	*9.6*	*9.6*	*9.0*	*8.7*	*8.3*	*8.0*	*7.1*
Horses >3 years	*22.1*	*23.7*	*25.4*	*27.1*	*28.7*	*30.4*	*32.3*	*35.8*	*36.3*	*37.5*	*40.2*	*40.4*	*41.7*	*43.3*	*44.3*	*45.8*	*46.9*	*48.1*	*49.4*	*51.1*	*53.4*	*49.0*	*50.1*	*50.2*
Mules and Asses	5.9	6.3	6.7	7.2	7.4	7.6	8.5	9.4	9.9	11.3	11.8	12.5	13.2	14.1	14.8	16.0	16.5	17.2	17.8	19.2	20.4	19.0	20.1	19.6
Mules	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*	*0.3*	*0.3*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.8*	*1.0*	*0.8*	*0.9*	*0.7*
Asses	*5.7*	*6.1*	*6.6*	*7.0*	*7.1*	*7.3*	*8.1*	*9.0*	*9.6*	*10.9*	*11.4*	*12.0*	*12.8*	*13.6*	*14.4*	*15.5*	*15.9*	*16.7*	*17.3*	*18.4*	*19.4*	*18.2*	*19.3*	*18.9*
Poultry [1)]	5938.2	5646.8	5501.6	6409.8	6330.3	6250.7	6440.5	6552.5	6739.6	6907.5	6983.0	6939.5	7338.6	7587.3	8060.7	8260.4	7670.2	8228.5	8542.8	8809.4	9024.9	9477.7	9954.6	10079.0
Growers	*718.9*	*664.2*	*709.6*	*719.2*	*716.8*	*714.4*	*732.1*	*732.9*	*793.5*	*760.9*	*831.7*	*745.3*	*753.9*	*809.0*	*853.1*	*867.7*	*888.4*	*901.8*	*919.0*	*966.7*	*925.5*	*969.7*	*1075.6*	*1054.5*
Layers	*3083.0*	*2645.4*	*2535.8*	*2517.6*	*2317.9*	*2118.2*	*2226.0*	*2277.5*	*2270.1*	*2222.8*	*2150.3*	*2069.5*	*2154.1*	*2117.2*	*2088.8*	*2188.5*	*2147.3*	*2197.7*	*2254.9*	*2318.3*	*2438.1*	*2437.0*	*2520.6*	*2588.6*
Broilers	*2019.9*	*2198.6*	*2095.5*	*2990.2*	*3110.6*	*3231.0*	*3293.2*	*3342.0*	*3502.3*	*3747.4*	*3807.8*	*3993.2*	*4298.2*	*4518.4*	*4970.8*	*5060.4*	*4481.3*	*5002.4*	*5300.4*	*5456.2*	*5580.1*	*5984.1*	*6282.1*	*6360.3*
Turkey	*94.7*	*117.4*	*140.1*	*162.8*	*166.5*	*170.2*	*173.8*	*184.4*	*157.8*	*154.6*	*172.6*	*123.0*	*123.9*	*133.8*	*138.8*	*132.3*	*137.1*	*112.5*	*53.8*	*52.4*	*58.1*	*57.8*	*51.2*	*55.1*
Other Poultry	*21.8*	*21.2*	*20.6*	*20.0*	*18.4*	*16.9*	*15.3*	*15.8*	*15.9*	*21.9*	*20.7*	*8.6*	*8.5*	*8.8*	*9.3*	*11.5*	*16.1*	*14.2*	*14.7*	*15.9*	*23.2*	*29.0*	*25.1*	*20.4*
Rabbits	60.9	56.8	52.7	48.7	44.6	40.5	36.5	37.4	32.8	31.3	27.9	25.1	33.4	31.1	20.5	25.4	24.5	27.2	24.9	27.8	35.0	34.3	27.9	27.5
Livestock NCAC	27.9	26.6	25.3	23.9	24.0	29.6	82.1	94.9	93.8	95.6	93.8	94.8	91.7	91.8	86.1	85.7	82.4	79.8	85.5	87.0	85.0	90.0	98.7	94.6
Total Sheep	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*53.4*	*66.9*	*67.1*	*67.3*	*66.9*	*69.3*	*66.7*	*68.7*	*63.4*	*62.4*	*60.3*	*58.8*	*63.4*	*65.5*	*62.5*	*65.0*	*73.5*	*69.5*
Fattening Sheep	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*26.7*	*33.3*	*33.1*	*34.8*	*34.0*	*34.9*	*33.5*	*34.8*	*32.1*	*31.4*	*30.1*	*30.0*	*33.1*	*34.6*	*33.2*	*36.5*	*43.4*	*40.7*
Milksheep	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.4*	*0.4*	*0.6*	*0.8*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.7*	*0.6*	*0.5*	*0.6*	*0.6*	*0.7*	*0.6*	*0.4*	*0.5*
Total Goats	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*5.7*	*5.5*	*5.2*	*5.4*	*7.6*	*7.4*	*7.7*	*8.5*	*7.9*	*8.9*	*10.8*	*9.9*	*9.1*	*10.6*	*9.7*	*10.1*	*13.6*	*13.6*	*13.6*
Goat Places	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*4.0*	*3.7*	*3.3*	*3.5*	*5.3*	*4.9*	*5.2*	*5.6*	*5.2*	*5.9*	*7.3*	*6.5*	*5.8*	*6.9*	*6.2*	*6.3*	*9.4*	*9.5*	*9.5*
Horses <3 years Non-Agr.	*5.0*	*4.7*	*4.5*	*4.3*	*4.9*	*5.4*	*4.8*	*4.1*	*3.8*	*3.8*	*3.2*	*2.8*	*2.4*	*2.1*	*1.9*	*1.7*	*1.6*	*1.5*	*1.4*	*1.3*	*1.3*	*1.2*	*1.2*	*1.1*
Horses >3 years Non-Agr.	*18.1*	*17.3*	*16.4*	*15.5*	*15.2*	*14.8*	*14.6*	*14.8*	*13.8*	*13.0*	*12.6*	*11.5*	*10.7*	*9.9*	*8.9*	*8.1*	*7.8*	*7.6*	*7.4*	*7.6*	*8.0*	*7.3*	*7.5*	*7.5*
Mules Non-Agr.	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.2*	*0.1*	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
Asses Non-Agr.	*4.7*	*4.5*	*4.2*	*4.0*	*3.8*	*3.6*	*3.7*	*3.7*	*3.6*	*3.8*	*3.6*	*3.4*	*3.3*	*3.1*	*2.9*	*2.7*	*2.7*	*2.6*	*2.6*	*2.7*	*2.9*	*2.7*	*2.9*	*2.8*

1) Other Poultry: Geese, Ducks, Ostriches, Quails

Additional data for estimating CH_4 and N_2O emission from Manure management

Table A – 36 Data for estimating manure management CH_4 emission factors (Table according to outline in IPCC 1997c, Tables B-1 to B-7).

Type	Weight kg [a]	Digestibility of Feed % [b]	Energy Intake MJ/day	Feed Intake kg/day	% Ash Dry Basis [b]	VS kg/head/day	B_0 m^3 CH_4/kg VS [b]
Mature Dairy Cattle	650	72	259 - 301	15.89 [c]	8.9 - 9.1	4.08 - 4.79	0.24
Other Mature Cattle	550	60	205.1	10.96 [c]	8	4.50	0.18
Fattening Calves	60 – 200	65	47.6	2.02 [a]	8	0.93	0.18
Pre-Weaned Calves	60 – 325	65	55.7	2.98 [a]	8	1.08	0.18
Breeding Calves	50 – 120	65	26.9	1.5 [a]	8	0.52	0.18
Breeding Cattle (4-12 months)	120 – 300	60	89.2	4.88 [a]	8	1.96	0.18
Breeding Cattle (> 1 year)	300 – 600	60	129.1	7.78 [a]	8	2.83	0.18
Fattening Calves (0-4 months)	70 – 175	65	55.6	3.27 [a]	8	1.08	0.18
Fattening Cattle (4-12 months)	175 – 550	60	124.6	6.82 [a]	8	2.73	0.18
Sheep	Not determined	60	21 - 24	1.09-1.24 [c]	8	0.4 [b]	0.19
Goats	Not determined	60	25 - 28	1.21-1.26 [c]	8	0.3 [b]	0.18
Horses	Not determined	70	107 - 108	7.73-7.83 [c]	4	1.72 [b]	0.33
Mules and Asses	Not determined	70	39 - 40	Not estimated	4	0.94 [b]	0.33
Swine	Not determined	75	26 - 32	Not estimated	2	0.31 [b]	0.45
Poultry	Not determined	Not estimated	1.2 - 1.6 [d]	Not estimated	Not estimated	0.01 [b]	0.37

a RAP 1999

b IPCC 1997c and IPCC 2006

c Flisch et al. 2009

d metabolizable energy (ME)

Table A – 37 Manure management system distribution in Switzerland 1990-2013.

MS Distribution		1990					1995					2002					2007					2010				
		%					%					%					%					%				
		Liquid / Slurry	Solid manure	Pasture range and paddock	Digesters	Other (Deep litter, Poultry manure)	Liquid / Slurry	Solid manure	Pasture range and paddock	Digesters	Other (Deep litter, Poultry manure)	Liquid / Slurry	Solid manure	Pasture range and paddock	Digesters	Other (Deep litter, Poultry manure)	Liquid / Slurry	Solid manure	Pasture range and paddock	Digesters	Other (Deep litter, Poultry manure)	Liquid / Slurry	Solid manure	Pasture range and paddock	Digesters	Other (Deep litter, Poultry manure)
Mature Dairy Cattle		63.7	27.6	8.3	0.4	0.0	65.7	24.4	9.5	0.4	0.0	65.3	16.2	18.0	0.5	0.0	67.4	13.6	17.7	1.3	0.0	66.9	14.3	16.9	1.8	0.0
Other Mature Cattle		41.2	32.1	26.3	0.4	0.0	39.3	34.1	26.2	0.4	0.0	39.7	20.7	39.1	0.5	0.0	49.5	20.2	29.0	1.3	0.0	47.9	17.9	32.4	1.8	0.0
Growing Cattle (weighted average)		47.5	31.7	15.8	0.4	4.5	48.4	30.9	15.9	0.4	4.5	42.1	25.4	27.5	0.5	4.5	45.6	23.9	25.3	1.3	4.0	45.2	25.6	23.4	1.8	4.1
	Fattening Calves	*14.3*	*0.0*	*0.0*	*0.4*	*85.2*	*15.0*	*0.0*	*0.0*	*0.4*	*84.6*	*21.6*	*0.0*	*0.3*	*0.5*	*77.6*	*21.8*	*0.0*	*0.2*	*1.3*	*76.7*	*16.8*	*0.0*	*0.2*	*1.8*	*81.1*
	Pre-Weaned Calves	*41.2*	*32.1*	*26.3*	*0.4*	*0.0*	*39.3*	*34.1*	*26.2*	*0.4*	*0.0*	*41.2*	*21.1*	*37.3*	*0.5*	*0.0*	*49.9*	*18.6*	*30.1*	*1.3*	*0.0*	*44.6*	*32.7*	*20.9*	*1.8*	*0.0*
	Breeding Cattle 1st Year	*37.0*	*48.5*	*14.1*	*0.4*	*0.0*	*38.0*	*47.4*	*14.2*	*0.4*	*0.0*	*33.7*	*38.8*	*27.0*	*0.5*	*0.0*	*40.9*	*34.5*	*23.3*	*1.3*	*0.0*	*43.3*	*33.4*	*21.5*	*1.8*	*0.0*
	Breeding Cattle 2nd Year	*45.3*	*28.9*	*25.4*	*0.4*	*0.0*	*47.3*	*26.7*	*25.6*	*0.4*	*0.0*	*37.8*	*23.4*	*38.4*	*0.5*	*0.0*	*41.4*	*20.8*	*36.5*	*1.3*	*0.0*	*43.2*	*20.7*	*34.3*	*1.8*	*0.0*
	Breeding Cattle 3rd Year	*50.5*	*29.0*	*20.0*	*0.4*	*0.0*	*51.4*	*27.9*	*20.3*	*0.4*	*0.0*	*42.2*	*22.5*	*34.8*	*0.5*	*0.0*	*45.6*	*21.3*	*31.8*	*1.3*	*0.0*	*46.2*	*21.4*	*30.6*	*1.8*	*0.0*
	Fattening Cattle	*70.0*	*24.1*	*0.0*	*0.4*	*5.5*	*66.4*	*27.7*	*0.0*	*0.4*	*5.6*	*67.3*	*26.8*	*2.2*	*0.5*	*3.2*	*62.3*	*29.2*	*4.3*	*1.3*	*2.9*	*57.6*	*33.2*	*4.0*	*1.8*	*3.4*
Sheep (weighted average)		0.0	0.0	30.1	0.0	69.9	0.0	0.0	30.3	0.0	69.7	0.0	0.0	33.2	0.0	66.8	0.0	0.0	39.2	0.0	60.8	0.0	0.0	33.7	0.0	66.3
	Fattening Sheep	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*33.5*	*0.0*	*66.5*	*0.0*	*0.0*	*40.2*	*0.0*	*59.8*	*0.0*	*0.0*	*34.5*	*0.0*	*65.5*
	Milksheep	*0.0*	*0.0*	*11.4*	*0.0*	*88.6*	*0.0*	*0.0*	*11.4*	*0.0*	*88.6*	*0.0*	*0.0*	*26.1*	*0.0*	*73.9*	*0.0*	*0.0*	*24.1*	*0.0*	*75.9*	*0.0*	*0.0*	*22.8*	*0.0*	*77.2*
Swine (weighted average)		98.8	0.0	0.0	1.2	0.0	98.7	0.0	0.0	1.3	0.0	98.0	0.3	0.1	1.5	0.0	94.5	0.1	1.2	4.1	0.0	94.0	0.3	0.1	5.6	0.0
	Piglets	*98.8*	*0.0*	*0.0*	*1.2*	*0.0*	*98.7*	*0.0*	*0.0*	*1.3*	*0.0*	*97.6*	*0.8*	*0.0*	*1.5*	*0.0*	*94.8*	*0.7*	*0.4*	*4.1*	*0.0*	*92.0*	*2.3*	*0.0*	*5.6*	*0.0*
	Fattening Pig over 25 kg	*98.8*	*0.0*	*0.0*	*1.2*	*0.0*	*98.7*	*0.0*	*0.0*	*1.3*	*0.0*	*98.1*	*0.3*	*0.2*	*1.5*	*0.0*	*94.4*	*0.0*	*1.5*	*4.1*	*0.0*	*94.2*	*0.0*	*0.2*	*5.6*	*0.0*
	Dry Sows	*98.8*	*0.0*	*0.0*	*1.2*	*0.0*	*98.7*	*0.0*	*0.0*	*1.3*	*0.0*	*98.4*	*0.0*	*0.1*	*1.5*	*0.0*	*94.8*	*0.1*	*1.0*	*4.1*	*0.0*	*94.2*	*0.0*	*0.2*	*5.6*	*0.0*
	Nursing Sows	*98.8*	*0.0*	*0.0*	*1.2*	*0.0*	*98.7*	*0.0*	*0.0*	*1.3*	*0.0*	*97.8*	*0.7*	*0.0*	*1.5*	*0.0*	*95.0*	*0.5*	*0.3*	*4.1*	*0.0*	*94.2*	*0.2*	*0.0*	*5.6*	*0.0*
	Boars	*98.8*	*0.0*	*0.0*	*1.2*	*0.0*	*98.7*	*0.0*	*0.0*	*1.3*	*0.0*	*97.7*	*0.5*	*0.2*	*1.5*	*0.0*	*94.7*	*0.0*	*1.2*	*4.1*	*0.0*	*92.5*	*1.2*	*0.6*	*5.6*	*0.0*
Buffalo (weighted average)		NA	NA	NA	NA	NA	47.5	26.8	25.6	0.0	0.0	38.1	23.5	38.4	0.0	0.0	42.3	21.1	36.5	0.0	0.0	44.5	21.2	34.3	0.0	0.0
	Bisons < 3 years	*45.6*	*29.0*	*25.4*	*0.0*	*0.0*	*47.5*	*26.8*	*25.6*	*0.0*	*0.0*	*38.1*	*23.5*	*38.4*	*0.0*	*0.0*	*42.3*	*21.1*	*36.5*	*0.0*	*0.0*	*44.5*	*21.2*	*34.3*	*0.0*	*0.0*
	Bisons > 3 years	*45.6*	*29.0*	*25.4*	*0.0*	*0.0*	*47.5*	*26.8*	*25.6*	*0.0*	*0.0*	*38.1*	*23.5*	*38.4*	*0.0*	*0.0*	*42.3*	*21.1*	*36.5*	*0.0*	*0.0*	*44.5*	*21.2*	*34.3*	*0.0*	*0.0*
Camels (weighted average)		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.0	0.0	33.5	0.0	66.5	0.0	0.0	40.2	0.0	59.8	0.0	0.0	34.5	0.0	65.5
	Llamas < 2 years	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*33.5*	*0.0*	*66.5*	*0.0*	*0.0*	*40.2*	*0.0*	*59.8*	*0.0*	*0.0*	*34.5*	*0.0*	*65.5*
	Llamas > 2 years	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*33.5*	*0.0*	*66.5*	*0.0*	*0.0*	*40.2*	*0.0*	*59.8*	*0.0*	*0.0*	*34.5*	*0.0*	*65.5*
	Alpacas < 2 years	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*33.5*	*0.0*	*66.5*	*0.0*	*0.0*	*40.2*	*0.0*	*59.8*	*0.0*	*0.0*	*34.5*	*0.0*	*65.5*
	Alpacas > 2 years	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*33.5*	*0.0*	*66.5*	*0.0*	*0.0*	*40.2*	*0.0*	*59.8*	*0.0*	*0.0*	*34.5*	*0.0*	*65.5*
Deer (weighted average)		0.0	0.0	30.7	0.0	69.3	0.0	0.0	30.7	0.0	69.3	0.0	0.0	33.5	0.0	66.5	0.0	0.0	40.2	0.0	59.8	0.0	0.0	34.5	0.0	65.5
	Fallow Deer	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*33.5*	*0.0*	*66.5*	*0.0*	*0.0*	*40.2*	*0.0*	*59.8*	*0.0*	*0.0*	*34.5*	*0.0*	*65.5*
	Red Deer	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*33.5*	*0.0*	*66.5*	*0.0*	*0.0*	*40.2*	*0.0*	*59.8*	*0.0*	*0.0*	*34.5*	*0.0*	*65.5*
Goats		0.0	0.0	13.6	0.0	86.4	0.0	0.0	13.6	0.0	86.4	0.0	0.0	12.2	0.0	87.8	0.0	0.0	7.1	0.0	92.9	0.0	0.0	10.0	0.0	90.0
	Goat Places	*0.0*	*0.0*	*13.6*	*0.0*	*86.4*	*0.0*	*0.0*	*13.6*	*0.0*	*86.4*	*0.0*	*0.0*	*12.2*	*0.0*	*87.8*	*0.0*	*0.0*	*7.1*	*0.0*	*92.9*	*0.0*	*0.0*	*10.0*	*0.0*	*90.0*
Horses (weighted average)		0.0	93.2	6.8	0.0	0.0	0.0	93.2	6.8	0.0	0.0	0.0	76.1	23.9	0.0	0.0	0.0	78.7	21.3	0.0	0.0	0.0	74.4	25.6	0.0	0.0
	Horses <3 years	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*61.8*	*38.2*	*0.0*	*0.0*	*0.0*	*61.7*	*38.3*	*0.0*	*0.0*	*0.0*	*66.4*	*33.6*	*0.0*	*0.0*
	Horses >3 years	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*79.3*	*20.7*	*0.0*	*0.0*	*0.0*	*81.9*	*18.1*	*0.0*	*0.0*	*0.0*	*75.6*	*24.4*	*0.0*	*0.0*
Mules and Asses (weighted average)		0.0	93.2	6.8	0.0	0.0	0.0	93.2	6.8	0.0	0.0	0.0	76.9	23.1	0.0	0.0	0.0	75.2	24.8	0.0	0.0	0.0	79.3	20.7	0.0	0.0
	Mules	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*76.9*	*23.1*	*0.0*	*0.0*	*0.0*	*75.2*	*24.8*	*0.0*	*0.0*	*0.0*	*79.3*	*20.7*	*0.0*	*0.0*
	Asses	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*76.9*	*23.1*	*0.0*	*0.0*	*0.0*	*75.2*	*24.8*	*0.0*	*0.0*	*0.0*	*79.3*	*20.7*	*0.0*	*0.0*
Poultry (weighted average)		0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.5	0.0	99.5	0.0	0.0	2.6	0.0	97.4	0.0	0.0	3.7	0.0	96.3	0.0	0.0	2.7	0.0	97.3
	Growers	*0.0*	*0.0*	*0.0*	*0.0*	*100.0*	*0.0*	*0.0*	*0.6*	*0.0*	*99.4*	*0.0*	*0.0*	*0.2*	*0.0*	*94.9*	*0.0*	*0.0*	*1.5*	*0.0*	*92.7*	*0.0*	*0.0*	*1.2*	*0.0*	*93.9*
	Layers	*0.0*	*0.0*	*0.0*	*0.0*	*100.0*	*0.0*	*0.0*	*0.6*	*0.0*	*99.6*	*0.0*	*0.0*	*5.1*	*0.0*	*99.4*	*0.0*	*0.0*	*7.3*	*0.0*	*98.8*	*0.0*	*0.0*	*6.1*	*0.0*	*99.7*
	Broilers	*0.0*	*0.0*	*0.0*	*0.0*	*100.0*	*0.0*	*0.0*	*0.4*	*0.0*	*99.6*	*0.0*	*0.0*	*0.6*	*0.0*	*96.9*	*0.0*	*0.0*	*1.2*	*0.0*	*96.9*	*0.0*	*0.0*	*0.3*	*0.0*	*98.1*
	Turkey	*0.0*	*0.0*	*0.0*	*0.0*	*100.0*	*0.0*	*0.0*	*0.4*	*0.0*	*99.4*	*0.0*	*0.0*	*3.1*	*0.0*	*99.8*	*0.0*	*0.0*	*3.1*	*0.0*	*98.5*	*0.0*	*0.0*	*1.9*	*0.0*	*98.8*
	Other Poultry [1)]	*0.0*	*0.0*	*0.0*	*0.0*	*100.0*	*0.0*	*0.0*	*0.0*	*0.0*	*100.0*	*0.0*	*0.0*	*3.1*	*0.0*	*96.9*	*0.0*	*0.0*	*3.1*	*0.0*	*96.9*	*0.0*	*0.0*	*1.2*	*0.0*	*98.8*
Rabbits		0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
Livestock NCAC (weighted average)		0.0	93.2	6.8	0.0	0.0	0.0	87.2	7.3	0.0	5.6	0.0	38.5	26.9	0.0	34.5	0.0	34.7	28.7	0.0	36.6	0.0	31.8	28.0	0.0	40.2
	Fattening Sheep Non-Agr.	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*33.5*	*0.0*	*66.5*	*0.0*	*0.0*	*40.2*	*0.0*	*59.8*	*0.0*	*0.0*	*34.5*	*0.0*	*65.5*
	Milksheep Non-Agr.	*0.0*	*0.0*	*11.4*	*0.0*	*88.6*	*0.0*	*0.0*	*11.4*	*0.0*	*88.6*	*0.0*	*0.0*	*26.1*	*0.0*	*73.9*	*0.0*	*0.0*	*24.1*	*0.0*	*75.9*	*0.0*	*0.0*	*22.8*	*0.0*	*77.2*
	Total Goats Non-Agr.	*NA*	*NA*	*NA*	*NA*	*NA*	*0.0*	*0.0*	*13.6*	*0.0*	*86.4*	*0.0*	*0.0*	*12.2*	*0.0*	*87.8*	*0.0*	*0.0*	*7.1*	*0.0*	*92.9*	*0.0*	*0.0*	*10.0*	*0.0*	*90.0*
	Horses <3 years Non-Agr.	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*61.8*	*38.2*	*0.0*	*0.0*	*0.0*	*61.7*	*38.3*	*0.0*	*0.0*	*0.0*	*66.4*	*33.6*	*0.0*	*0.0*
	Horses >3 years Non-Agr.	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*79.3*	*20.7*	*0.0*	*0.0*	*0.0*	*81.9*	*18.1*	*0.0*	*0.0*	*0.0*	*75.6*	*24.4*	*0.0*	*0.0*
	Mules Non-Agr.	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*76.9*	*23.1*	*0.0*	*0.0*	*0.0*	*75.2*	*24.8*	*0.0*	*0.0*	*0.0*	*79.3*	*20.7*	*0.0*	*0.0*
	Asses Non-Agr.	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*76.9*	*23.1*	*0.0*	*0.0*	*0.0*	*75.2*	*24.8*	*0.0*	*0.0*	*0.0*	*79.3*	*20.7*	*0.0*	*0.0*

1) Other Poultry: Geese, Ducks, Ostriches, Quails

Table A – 38 Nitrogen excretion of livestock in Switzerland 1990-2013.

Nitrogen Excretion		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
		kg N/head or place/year																							
Mature Dairy Cattle		102.7	103.5	103.6	104.6	104.6	105.5	105.1	106.5	107.7	108.8	109.7	110.2	111.1	112.1	113.2	113.2	113.3	113.9	114.2	114.7	114.9	115.0	114.9	114.7
Other Mature Cattle		80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0
Growing Cattle (weighted average)		33.1	33.1	33.2	33.1	33.3	33.4	33.3	33.6	33.3	32.8	33.6	33.3	33.3	33.3	33.2	33.1	33.2	33.2	33.2	33.4	33.4	33.4	33.3	33.3
	Fattening Calves	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*
	Pre-Weaned Calves	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*
	Breeding Cattle 1st Year	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*
	Breeding Cattle 2nd Year	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*
	Breeding Cattle 3rd Year	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*
	Fattening Cattle	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*
Sheep (weighted average)		7.5	7.6	7.5	7.6	7.6	7.6	7.6	7.6	7.6	8.1	8.1	8.1	8.0	8.1	8.1	8.1	8.2	8.3	8.2	8.5	8.5	8.5	8.5	8.6
	Fattening Sheep	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*
	Milksheep	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*
Swine (weighted average)		13.4	13.4	13.3	13.1	13.0	12.8	12.7	12.3	12.0	10.9	10.5	10.1	9.8	9.6	9.5	9.4	9.2	9.1	9.2	9.2	9.2	9.2	9.1	9.2
	Piglets	*4.6*	*4.6*	*4.6*	*4.6*	*4.6*	*4.6*	*4.6*	*4.6*	*4.6*	*4.6*	*4.6*	*4.6*	*4.6*	*4.6*	*4.5*	*4.5*	*4.5*	*4.4*	*4.4*	*4.4*	*4.4*	*4.4*	*4.4*	*4.4*
	Fattening Pig over 25 kg	*17.0*	*16.9*	*16.9*	*16.8*	*16.7*	*16.7*	*16.2*	*15.6*	*15.1*	*14.6*	*14.1*	*13.5*	*13.0*	*12.8*	*12.6*	*12.3*	*12.1*	*11.9*	*12.0*	*12.0*	*12.1*	*12.1*	*12.1*	*12.1*
	Dry Sows	*24.3*	*24.3*	*24.3*	*24.3*	*24.3*	*24.3*	*23.5*	*22.8*	*22.0*	*21.3*	*20.5*	*19.8*	*19.0*	*19.1*	*19.2*	*19.2*	*19.3*	*19.4*	*19.5*	*19.6*	*19.7*	*19.7*	*19.7*	*19.7*
	Nursing Sows	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*46.8*	*46.0*	*45.2*	*44.4*	*43.6*	*42.8*	*42.0*	*42.4*	*42.9*	*43.3*	*43.7*	*44.2*	*43.2*	*42.2*	*41.2*	*41.2*	*41.2*	*41.2*
	Boars	*20.5*	*20.5*	*20.5*	*20.5*	*20.5*	*20.5*	*20.0*	*19.5*	*19.0*	*18.6*	*18.1*	*17.6*	*17.1*	*17.2*	*17.3*	*17.3*	*17.4*	*17.5*	*17.7*	*17.9*	*18.2*	*18.2*	*18.2*	*18.2*
Buffalo (weighted average)		NA	NA	36.5	37.8	37.5	37.2	37.3	37.1	37.3	34.9	41.1	37.5	38.8	37.4	38.5	38.7	38.0	34.9	34.4	36.5	37.3	38.4	36.9	36.9
	Bisons < 3 years	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*
	Bisons > 3 years	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*
Camels (weighted average)		NA	NA	NA	NA	NA	NA	15.3	15.3	15.3	14.0	14.1	13.0	13.3	13.7	13.3	12.8	12.8	12.8	12.8	12.8	12.6	12.7	12.8	12.9
	Llamas < 2 years	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*
	Llamas > 2 years	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*
	Alpacas < 2 years	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*
	Alpacas > 2 years	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*
Deer (weighted average)		20.0	20.4	21.2	21.6	21.8	21.9	23.6	21.9	21.7	22.0	22.3	22.1	22.4	21.8	22.0	21.9	22.1	22.1	22.4	22.5	22.4	22.4	22.5	23.0
	Fallow Deer	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*
	Red Deer	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*
Goats		10.5	10.6	10.6	10.5	10.5	10.4	10.4	10.4	10.6	10.6	10.6	10.7	10.4	10.7	10.5	10.5	10.6	10.5	10.5	10.7	10.6	10.8	10.8	10.9
	Goat Places	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*
Horses (weighted average)		43.6	43.6	43.6	43.6	43.5	43.5	43.5	43.6	43.6	43.5	43.6	43.6	43.6	43.6	43.7	43.7	43.7	43.7	43.7	43.7	43.7	43.7	43.7	43.8
	Horses <3 years	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*
	Horses >3 years	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*
Mules and Asses (weighted average)		15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7
	Mules	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*
	Asses	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*
Poultry (weighted average)		0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Growers	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*
	Layers	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*
	Broilers	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.5*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*
	Turkey	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*
	Other Poultry [1)]	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*
Rabbits		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Livestock NCAC (weighted average)		38.8	38.8	38.8	38.8	39.0	33.8	16.7	15.3	14.8	14.8	14.5	13.7	13.5	13.1	12.9	12.5	12.4	12.5	12.2	12.3	12.6	12.6	12.5	12.6
	Fattening Sheep Non-Agr.	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*
	Milksheep Non-Agr.	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*
	Total Goats Non-Agr.	*NA*	*NA*	*NA*	*NA*	*NA*	*11.3*	*10.6*	*10.3*	*10.5*	*11.1*	*10.5*	*10.8*	*10.6*	*10.4*	*10.6*	*10.9*	*10.5*	*10.3*	*10.5*	*10.1*	*10.0*	*11.1*	*11.2*	*11.2*
	Horses <3 years Non-Agr.	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*
	Horses >3 years Non-Agr.	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*
	Mules Non-Agr.	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*
	Asses Non-Agr.	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*	*15.7*

1) Other Poultry: Geese, Ducks, Ostriches, Quails

Additional data for estimating N_2O emission from Agricultural soils

Table A – 39 Additional data for estimating N_2O emission from crop residues (2013).

2013		Total crop production kg DM	Nitrogen incorporated with crop residues $F_{(CR)}$ t N	N_2O emissions from crop residues t N_2O
1. Cereals	Wheat	396'581'100	1'661	26.11
	Barley	140'113'150	714	11.22
	Maize	105'328'600	1'004	15.78
	Oats	6'743'900	42	0.66
	Rye	8'718'450	37	0.58
	Other:			
	Triticale	42'860'400	210	3.30
	Spelt	11'025'350	101	1.59
	Mix of Fodder Cereals	690'200	4	0.06
	Mix of Bread Cereals	103'700	0	0.01
	Millet	85'500	0	0.00
2. Pulse	Dry Beans	930'750	37	0.58
	Peas (Eiweisserbsen)	10'454'150	307	4.83
	Soybeans	3'020'050	124	1.95
	Leguminous Vegetables	2'667'511	387	6.08
	Lupines	172'480	7	0.11
3. Tuber and Root	Potatoes	73'153'280	267	4.20
	Other:			
	Fodder Beet	8'240'000	66	1.04
	Sugar Beet	302'783'580	2'725	42.82
5. Other	Fruit	47'370'500	189	2.98
	Grass	6'139'201'493	21'794	342.48
	Green Corn	102'820'214	47	0.74
	Non-Leguminous Vegetables	53'096'171	495	7.77
	Rape	65'259'000	953	14.98
	Renewable Energy Crops	1'782'000	26	0.41
	Silage Corn	604'824'786	347	5.46
	Sunflowers	7'285'350	154	2.42
	Tobacco	1'051'000	27	0.43
	Vine	21'257'800	128	2.00
	Oil Squash	4'253	0	0.00
	Oil Hemp	4'500	0	0.00
	Oil Flax	417'600	3	0.05
	Hops	6'200	0	0.00
	Medicinal Plants and Herbs	338'000	9	0.14
Total Non-leguminous		2'001'944'585	9'211	144.75
Total Leguminous		17'244'941	863	13.56
Total excluding Grass		2'019'189'526	10'074	158.31
Total including Grass		8'158'391'019	31'868	500.78

Table A – 40 Additional data for estimating N_2O emission from crop residues (fractions)(2013).

2013		Residue/ Crop ratio kg/kg	Dry matter fraction of residue kg/kg	Nitrogen content of residues kg/kg
1. Cereals	Wheat	1.15	0.85	0.0037
	Barley	1.00	0.85	0.0051
	Maize	1.11	0.85	0.0086
	Oats	1.27	0.85	0.0049
	Rye	1.17	0.85	0.0036
	Other :			
	Triticale	1.25	0.85	0.0039
	Spelt	1.56	0.85	0.0059
	Mix of Fodder Cereals	1.00	0.85	0.0051
	Mix of Bread Cereals	1.17	0.85	0.0037
	Millet	0.20	0.90	0.0070
2. Pulse	Dry Beans	1.13	0.85	0.0353
	Peas (Eiweisserbsen)	1.25	0.85	0.0235
	Soybeans	1.00	0.85	0.0412
	Other:			
	Leguminous Vegetables	3.87	0.16	0.0328
	Lupines	1.00	0.85	0.0412
3. Tuber and Root	Potatoes	0.47	0.13	0.0127
	Other :			
	Fodder Beet	0.41	0.15	0.0233
	Sugar Beet	0.67	0.15	0.0220
5. Other	Fruit	NA	0.17	0.0040
	Grass	0.26	NA	0.0215
	Green Corn	0.05	0.32	0.0091
	Non-Leguminous Vegetables	0.46	0.13	0.0230
	Rape	1.86	0.85	0.0083
	Renewable Energy Crops	1.86	0.85	0.0083
	Silage Corn	0.05	0.32	0.0115
	Sunflowers	2.00	0.60	0.0150
	Tobacco	1.18	NA	0.0221
	Vine	NA	0.20	0.0060
	Oil Squash	0.46	0.13	0.0230
	Oil Hemp	4.62	0.85	0.0106
	Oil Flax	1.25	0.85	0.0071
	Hops	NA	0.20	NA
	Medicinal Plants and Herbs	1.18	NA	0.0221

Table A – 41 NH_3 and NO_x emission factors for Indirect N_2O emissions from managed soils 1990-2013.

Emission Factors Volatilisation	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
	%																							
NH_3 from application of animal manure N ($Frac_{GASMT}$)	26.94	26.97	26.96	26.91	27.00	27.07	26.71	26.35	25.98	25.63	25.29	24.94	24.54	24.71	24.88	25.06	25.31	25.53	25.01	24.41	23.82	23.82	23.80	23.81
Mature Dairy Cattle	29.41	29.43	29.46	29.48	29.51	29.53	29.26	28.97	28.67	28.37	28.05	27.71	27.37	27.50	27.63	27.76	27.89	28.02	27.39	26.76	26.13	26.13	26.13	26.13
Other Mature Cattle	27.35	27.29	27.23	27.17	27.11	27.05	26.80	26.53	26.24	25.94	25.61	25.25	24.87	25.52	26.13	26.71	27.25	27.76	27.26	26.74	26.21	26.21	26.21	26.21
Growing Cattle (weighted average)	27.67	27.67	27.68	27.71	27.77	27.81	27.47	27.16	26.78	26.33	26.07	25.62	25.20	25.63	26.05	26.45	26.88	27.30	26.75	26.27	25.76	25.74	25.72	25.72
Sheep (weighted average)	8.81	8.92	9.03	9.14	9.25	9.36	9.36	9.37	9.36	9.36	9.34	9.33	9.32	9.69	10.08	10.48	10.89	11.32	11.19	11.07	10.96	10.96	10.96	10.96
Swine (weighted average)	22.85	22.77	22.68	22.60	22.52	22.43	22.10	21.76	21.40	21.02	20.62	20.21	19.77	20.03	20.29	20.55	20.79	21.06	20.41	19.77	19.12	19.13	19.15	19.14
Buffalo (weighted average)	NA	NA	28.38	28.43	28.49	28.54	28.30	28.05	27.78	27.49	27.17	26.84	26.48	26.86	27.23	27.61	27.98	28.35	27.61	26.89	26.18	26.18	26.18	26.18
Camels (weighted average)	NA	NA	NA	NA	NA	NA	9.36	9.37	9.39	9.40	9.42	9.43	9.44	9.82	10.20	10.60	11.01	11.44	11.28	11.13	10.98	10.98	10.98	10.98
Deer (weighted average)	8.79	8.90	9.01	9.13	9.24	9.35	9.36	9.37	9.39	9.40	9.42	9.43	9.44	9.82	10.20	10.60	11.01	11.44	11.28	11.13	10.98	10.98	10.98	10.98
Goats	9.05	9.17	9.28	9.40	9.51	9.62	9.45	9.28	9.11	8.93	8.76	8.59	8.42	9.42	10.37	11.28	12.15	12.98	11.68	10.30	8.85	8.85	8.85	8.85
Horses (weighted average)	9.23	9.35	9.47	9.58	9.70	9.82	9.64	9.46	9.26	9.05	8.82	8.57	8.31	8.63	8.95	9.26	9.57	9.88	9.82	9.77	9.72	9.71	9.72	9.73
Mules and Asses (weighted average)	9.23	9.35	9.47	9.58	9.70	9.82	9.55	9.28	8.98	8.67	8.34	7.99	7.61	8.03	8.46	8.88	9.31	9.73	10.47	11.18	11.85	11.85	11.85	11.85
Poultry (weighted average)	13.76	14.00	14.25	14.48	14.72	14.96	14.79	14.64	14.47	14.30	14.11	13.94	13.78	13.47	13.14	12.88	12.67	12.30	12.91	13.64	14.38	14.38	14.38	14.38
Rabbits	9.33	9.33	9.33	9.33	9.33	9.33	9.26	9.19	9.11	9.04	8.97	8.90	8.83	8.80	8.77	8.74	8.72	8.69	8.75	8.82	8.89	8.89	8.89	8.89
Livestock NCAC (weighted average)	9.23	9.35	9.47	9.58	9.70	9.81	9.56	9.41	9.27	9.13	8.97	8.84	8.68	9.12	9.54	10.03	10.44	10.86	10.71	10.49	10.27	10.23	10.29	10.27
NH_3 from urine and dung N deposited on PR&P ($Frac_{GASPT}$)	4.96	4.97	4.98	4.99	4.99	5.00	5.02	5.03	5.05	5.06	5.07	5.07	5.08	5.10	5.13	5.16	5.17	5.20	5.16	5.13	5.10	5.11	5.11	5.12
Mature Dairy Cattle	4.95	4.94	4.94	4.94	4.94	4.93	4.91	4.90	4.89	4.88	4.87	4.86	4.86	4.85	4.84	4.82	4.81	4.80	4.80	4.80	4.80	4.80	4.80	4.80
Other Mature Cattle	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98
Growing Cattle (weighted average)	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98
Sheep (weighted average)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Swine (weighted average)	NA	NA	NA	NA	NA	NA	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00
Buffalo (weighted average)	NA	NA	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98
Camels (weighted average)	NA	NA	NA	NA	NA	NA	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Deer (weighted average)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Goats	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Horses (weighted average)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Mules and Asses (weighted average)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Poultry (weighted average)	NA	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00
Rabbits	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Livestock NCAC (weighted average)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
NH_3 from commercial fertiliser N ($Frac_{GASFi}$)	6.10	5.37	5.38	5.62	5.82	5.83	5.85	5.65	5.30	5.17	5.34	5.02	4.99	4.66	4.75	4.34	4.19	4.61	4.31	4.04	4.11	4.22	3.99	4.16
Urea	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Other Mineral Fertilisers	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Recycling Fertilisers (weighted average)	17.58	18.04	18.48	18.91	19.33	19.74	19.92	20.06	20.17	20.25	20.27	19.22	18.03	16.70	15.19	13.47	12.90	12.32	11.83	10.91	9.58	9.58	9.58	9.58
Sewage Sludge	20.00	20.79	21.58	22.37	23.15	23.94	24.37	24.79	25.22	25.64	26.07	26.07	26.07	26.07	26.07	26.07	26.07	26.07	26.07	26.07	26.07	26.07	26.07	26.07
Compost	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43
Digestate Liquid	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	27.00	24.00	21.00	21.00	21.00	21.00
Digestate Solid	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
NH_3 from Agricultural Soils (kg/ha/year)	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
NH_3 from Alpine Area (kg/ha/year)	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
NO_x from applied fertilisers ($Frac_{NOXA}$)	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
NO_x from urine and dung N deposited on PR&P ($Frac_{NOXP}$)	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55

Annex 4: National energy balance and reference approach

A4.1 Swiss Energy balance: energy flows

The diagram shows a summary of the Swiss energy flow 2013 as published by the Swiss Federal Office of Energy (SFOE 2014). Diagram languages are German and French. The energy balace is also provided in tabular form in Table 3-9.

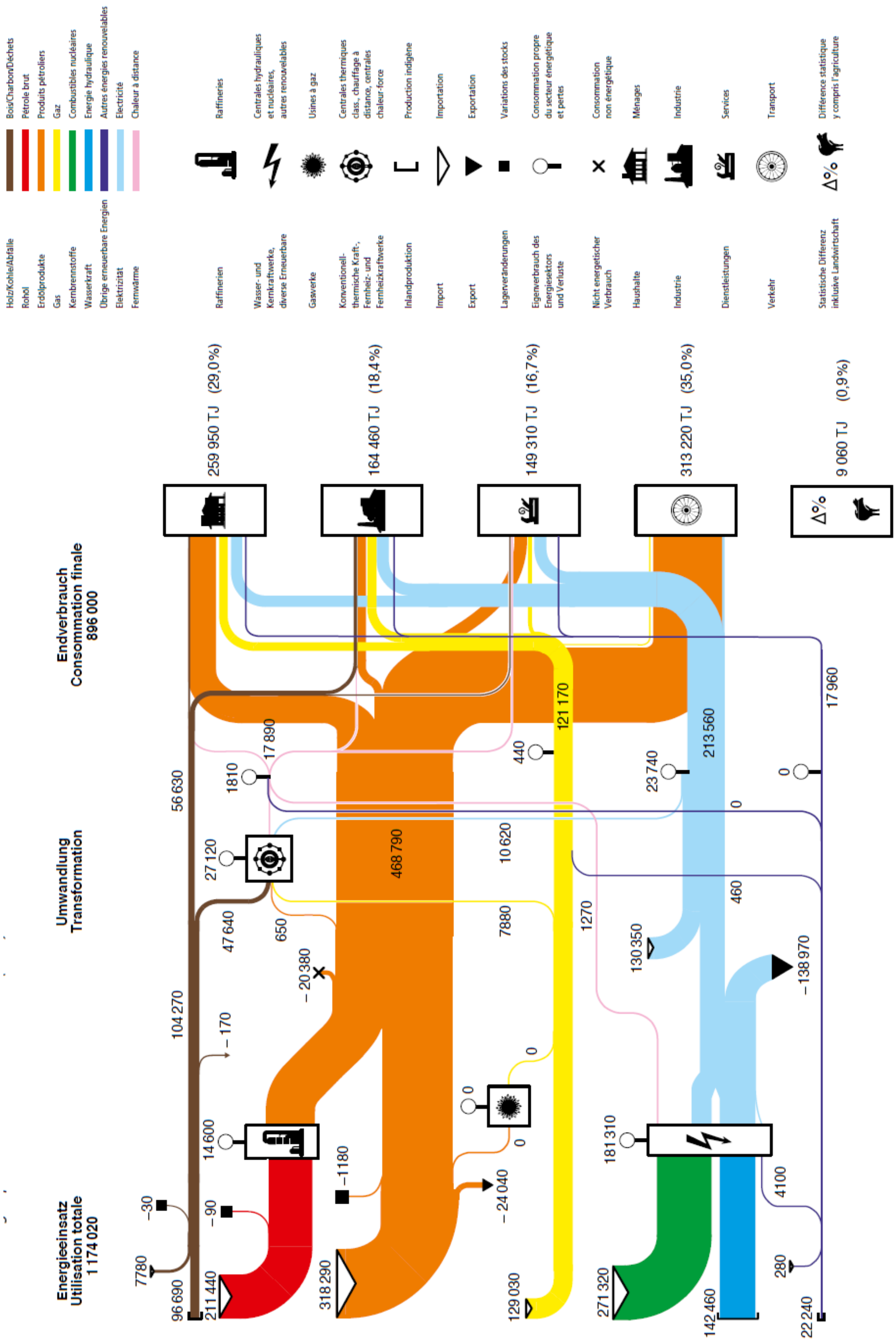


Figure A – 2 Energy flow in Switzerland 2013 in TJ (SFOE 2014)

A4.2 Differences between IEA data and the reference approach

Reviewers have repeatedly asked for explanations of the apparent differences between the energy data held by the International Energy Agency (IEA) and the data reported in the reference approach. In order to clarify the pertaining issues, the reasons for the major differences are given below. Data for the year 2010 are used to illustrate the description.

General remarks

The net calorific values used by IEA differ from those used in the GHG inventory. In order to avoid differences caused by the conversion with different NCV, the comparison between IEA and the reference approach is made in kt.

Stock changes as reported by IEA are only including primary stocks (IEA 2005), while the reporting in the reference approach includes secondary and tertiary stocks. This results in a particularly large difference for gas oil, as retailers and end-consumers hold considerable amounts of heating fuel on stock. The IEA subsumes secondary and tertiary stock changes under statistical difference.

All data regarding liquid fuel consumption reported by the IEA includes fuel consumption in Liechtenstein (Geographical coverage in IEA 2012). For reporting purposes under the UNFCCC, consumption of Liechtenstein is subtracted.

Data sources used for the comparison shown in table A-40 below are:

- Switzerland’s greenhouse gas inventory 1990-2011, submission of 15. April 2013, CRF-table 1.A(b), (FOEN 2013).
- Energy statistics of OECD countries (2012 Edition), (IEA 2012).

Liquid fuels

The total amount of liquid fuel consumption as reported in the greenhouse gas inventory is 11'052 kt. There is a difference of 13 kt (0.1%) between CRF and IEA. This difference is primarily caused by the different methodology used for aviation bunkers (see below).

Crude oil

Crude oil in the reference approach contains additives, while IEA lists them separately (data in italics in table A-44. The difference between CRF and IEA is smaller than 0.1% if the sum of additives, refinery feedstocks and crude oil is considered.

Gasoline

The comparison is made for motor gasoline only. Aviation gasoline is included under aviation fuels. Gasoline reported by IEA includes gasoline used in Liechtenstein (LIE), which is subtracted for reporting under the UNFCCC. The difference between CRF and IEA is approximately 0.1%, if the consumption of LIE is taken into account.

Aviation fuels

The different aviation fuels are aggregated in the greenhouse gas inventory. For comparison of IEA and reference approach, all aviation fuels are summed up. The difference between IEA and reference approach if considering the apparent final consumption is 12 kt (approximately 1% of imports). This difference is largely due to a different methodology used to estimate international bunker. Aviation bunkers have to be reported monthly to the IEA. As the tier 3 approach used for the greenhouse gas inventory is not available on a monthly basis, the international bunker fuel estimate of IEA consists of the total consumption at the two international airports in Zurich and Geneva, while all remaining fuel use is considered domestic. The reporting in the national greenhouse gas inventory is based on a much more detailed approach, where information on single flights is taken into account. Due to the different approach, the numbers are somewhat different. However, the order of magnitude is the same, and the information in the inventory is based on a higher-tier method and presumably more accurate.

Diesel and gas oil

The IEA numbers include diesel and gas oil used in Liechtenstein. Furthermore, stock changes are reported differently in the CRF and by the IEA. Secondary and tertiary stock changes are subsumed under statistical difference by the IEA, while they are included in the stock change reported in the reference approach. If the statistical difference is taken into account, the difference in the apparent consumption is less than 0.1%.

Residual fuel oil

Data agree between IEA and UNFCCC. It seems as if there is a rounding error in the imported amounts, leading to an apparent difference of 1 kt. According to the foreign trade statistics, 33'693 t of residual fuel oil had been imported in 2010.

Bitumen

Bitumen is a main feedstock in the greenhouse gas inventory. Data between IEA and the reference approach compare well. Again, small differences are likely due to the use of rounded values, leading to apparent differences of the order of 1-2 kt.

Petroleum coke

There are considerable differences (26 kt) in the reported numbers for petroleum coke import. The reason for this apparent difference is that for IEA, all petroleum coke is reported together. In the greenhouse gas inventory submitted in 2013, however, only the petroleum coke used as a fuel was reported under petroleum coke, while calcined petroleum coke was reported together with “other oil” as feedstocks. This is largely a consequence of the treatment of fuels and feedstocks in the Swiss energy statistic (SFOE 2012).

Lubricants

There are small differences between IEA and the reference approach, as the data reported to the IEA comprises a slightly different set of customs tariff headings for lubricants to the one used for the Swiss energy statistic. The substances not reported under lubricants in the reference approach are reported under other oil.

Liquefied petroleum gas (LPG)

The reporting of liquefied petroleum gas in the greenhouse gas inventory includes white spirit and lamp oil. As for petroleum coke, IEA numbers include fuels that are used as feedstocks, while in the reference approach, only liquefied petroleum gas, white spirit and lamp oil used as fuels are reported under liquefied petroleum gas. The difference in apparent consumption between IEA and the reference approach is 3 kt (0.03% of total liquid fuel consumption).

Other oil products

In the greenhouse gas inventory, all other oil products are reported together, while IEA has a finer degree of disaggregation. As already mentioned above, the share of petroleum coke that is used as a feedstock is reported under other oil in the greenhouse gas inventory. Therefore, the difference between IEA and the reference approach corresponds largely to the difference in apparent consumption of petroleum coke.

Solid fuels

Solid fuels play only a minor role in Switzerland (246 kt) and are reported in good agreement.

Gaseous fuels

In the greenhouse gas inventory, the amount of gas reported under 1B2b Fugitive emissions is subtracted from the total gas import as reported by IEA, as this gas is not used for energy purposes. Taking this into account the difference is of the order of 2 TJ.

Table A – 42 Comparison of the IEA energy statistic with the Reference Approach for the year 2010. Numbers in italics are fuels that are reported in a finer disaggregation in the IEA energy statistic than in the Reference Approach. Numbers in bold aggregate the data to the level of disaggregation used in the Reference Approach.

CRF vs. IEA (2010)	Import		Export		Bunker		Stock change		Stat.diff.	LIE	Consumption	
Gg	IEA	CRF	IEA	CRF	IEA	CRF	IEA	CRF	IEA	CRF	IEA	CRF
Crude oil	*4'488*	*4'546*					*0*	*1*	*0*		*4'488*	*4'547*
Refinery feedstocks	*3*						*1*		*2*		*6*	
Additives/blending components	*51*						*-1*		*2*		*52*	
											4'546	**4'547**
Motor gasoline	1'850	1'838					-9	-6	4	15	**1'830**	**1'832**
Aviation gasoline	*7*						*-2*		*-1*		*4*	
Kerosene type jet fuel	*1'354*	*1'362*			*-1'367*	*-1'352*		*2*	*6*		*-7*	*12*
Other Kerosene	*3*										*3*	
											0	**12**
Gas/diesel oil	3'510	3'485	-21	-39	-10	-11	38	1'072	1'020	27	**4'510**	**4'507**
Fuel oil	33	34	-323	-316			-17	-17	7		**-300**	**-299**
Liquefied petroleum gases (LPG)	*50*	*54*	*-24*	*-25*						*0.1*	*26*	*29*
White spirit & SBP	*7*								*-1*		*6*	
											32	**29**
Bitumen	317	318	-2	-2							**315**	**317**
Lubricants	86	72	-38	-16					7		**55**	**56**
Petroleum coke	73	47									**73**	**47**
Naphtha	*1*						*5*		*-1*		*5*	
Paraffin waxes	*1*										*1*	
Non-specified oil products / other oil	*4*	*63*	-	*-23*			-	*-6*			*4*	*33*
											10	**33**
Liquid fuels											**11'039**	**11'052**
Anthracite	*7*										*7*	
Other bituminous coal	*123*	*152*					*36*	*32*			*159*	*184*
Lignite	*66*	*62*					*-4*				*62*	*62*
Coke oven coke	*18*										*18*	
Solid fuels											**246**	**246**
Natural gas (TJ, NCV)	126'014	125'627									126'014	125'627
Fugitive emissions (TJ, NCV)		389										389
Gaseous fuels											**126'014**	**126'016**

Annex 5: Additional information

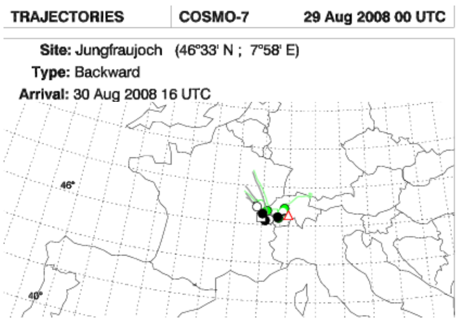
A 5.1 Independent verification of the National Swiss Inventory for F-gases

Introduction:
Since 2000 the Swiss Federal Laboratories for Materials Science and Technology (Empa) performs continuous measurements of halogenated greenhouse gases at the high-Alpine site of Jungfraujoch (3580 m asl). These measurements are used for the independent estimation of fluorinated greenhouse gases (HFC, SF_6) emissions from Switzerland and neighbouring countries and can serve as a verification tool for their Swiss emissions. For this verification the so-called tracer-ratio method is applied, where Swiss HFC and SF_6 pollution events are scaled to concurrent pollution events of carbon monoxide (CO) and then multiplied by the Swiss CO emission inventory. Other methods that rely on atmospheric observations are also being developed at Empa for future usage. Similar approaches are also used for independent verification of greenhouse gas emissions in the United Kingdom (UK MetOffice – using measurements from Mace Head, Ireland) and in Australia (CSIRO – using measurements from Cape Grim, Tasmania).

Method description:
For yearly estimates of Swiss emissions of HFCs and SF_6 based on data from Jungfraujoch, only periods are used when the air masses at the high-Alpine station of Jungfraujoch are predominantly influenced by emissions from Switzerland. The number of events which can be used each year depends on the meteorological conditions and is between 7-15 days per year. The process to select these periods is shown in Figure A – 3 and is shortly described here. First, the trajectories from the COSMO-model from MeteoSwiss are screened for periods when the Jungfraujoch site has been under the influence of air masses which were within the Swiss boundary layer for the last 48 hours. Second, for these periods mixing ratios of HFCs and SF_6 are compared with those of CO. Periods which show a concurrent increase for both groups of compounds are selected for the independent verification of Swiss emissions, as this is taken as an indication of thorough mixing of Swiss emissions during the transport to the measurement site. Third, the emissions are calculated for each case/day using the formula in Figure A – 3. The resulting emissions are only used for the annual emission estimate if they are within three standard deviations of the average (Grubbs test). This criterion is met by approximately 90% of the selected data. Finally, annual emissions are estimated as the median from these individual cases. These annual estimates are merged to a 3-year annual average centred over a 3-year period (e.g. the estimate for 2009 emissions is calculated by using data from 2008–2010). The error of the estimates based on data from Jungfraujoch has been assessed by using the range of 25%-75% percentiles of the estimates from single pollution events, since 2009. For estimates between 2001-2008 the average of the 2009-2011 errors has been taken. An additional absolute error could occur if the Swiss emissions of CO are over/underestimated by the inventory. This would linearly be transmitted to the emissions of the fluorinated greenhouse gases.

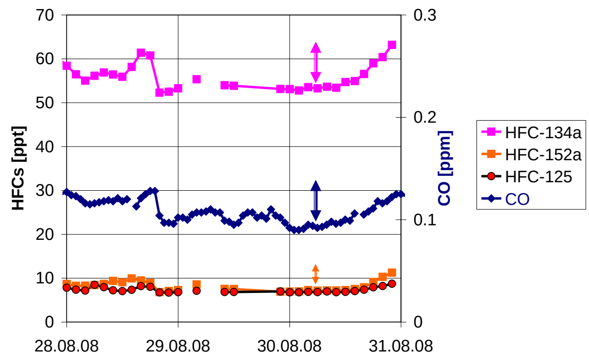
1st step:

Selection of periods with Swiss influence 2 days prior to the measurements by using COSMO trajectories from MeteoSwiss



2nd step:

Confine selected periods by using only periods with concurrent enhancement of CO and HFCs



$$E_H = E_{CO} \times \frac{\Delta H}{\Delta CO}$$

E_H = Swiss emission HFC

E_{CO} = Swiss Emission of CO (e.g. in 2013 209 kt)

ΔH = HFC concentration increase

ΔCO = CO concentration increase

Swiss-emission estimation:

Median of all cases per year

3-year average

Figure A – 3 Description of the procedure to estimate annual emissions of HFCs from Switzerland by using continuous measurements of HFCs at Jungfraujoch (Switzerland).

Results and Discussion:

In the following, Swiss emissions of five HFCs (HFC-134a, HFC-125, HFC-152a, HFC-143a, HFC-32) are estimated based on data from Jungfraujoch and are compared to the emission estimate of the Swiss greenhouse gas inventory. Further emission estimates of other HFC's and other fluorinated greenhouse gases (e.g. SF_6) will be added in future National Inventory Reports (NIR) upon availability.

HFC-134a

HFC-134a is the most important anthropogenic HFC. Its main source is the diffuse emission from its usage as cooling agent in mobile air conditioners (MACs). Further relevant applications are the usage as propellant and the usage as cooling agent in the industrial and commercial refrigeration and in stationary air conditioners and heat pumps. The stock of HFC-134a in MACs and the related emissions have been steadily increasing over the past years. The stabilization of the total emissions between 2005 and 2010 is related to the decreasing HFC use as propellant and optimizations in the industrial and commercial refrigeration. Increasing tendencies are found again in the measurement-based estimates after 2010 due to the still growing stock of HFC-134a in refrigeration and air-conditioning equipment and due to new applications using HFC-134a for research (i.e. as tracer gas). Estimated emissions based on measurements at Jungfraujoch agree fairly well with the emission estimates of the Swiss greenhouse gas inventory. The emissions according to the inventory are slightly higher than the ones based on measurements. Data for both methods often agreed within the estimated uncertainty of 25% until 2007. The gap got larger within recent years, albeit a concurrent increasing trend was seen.

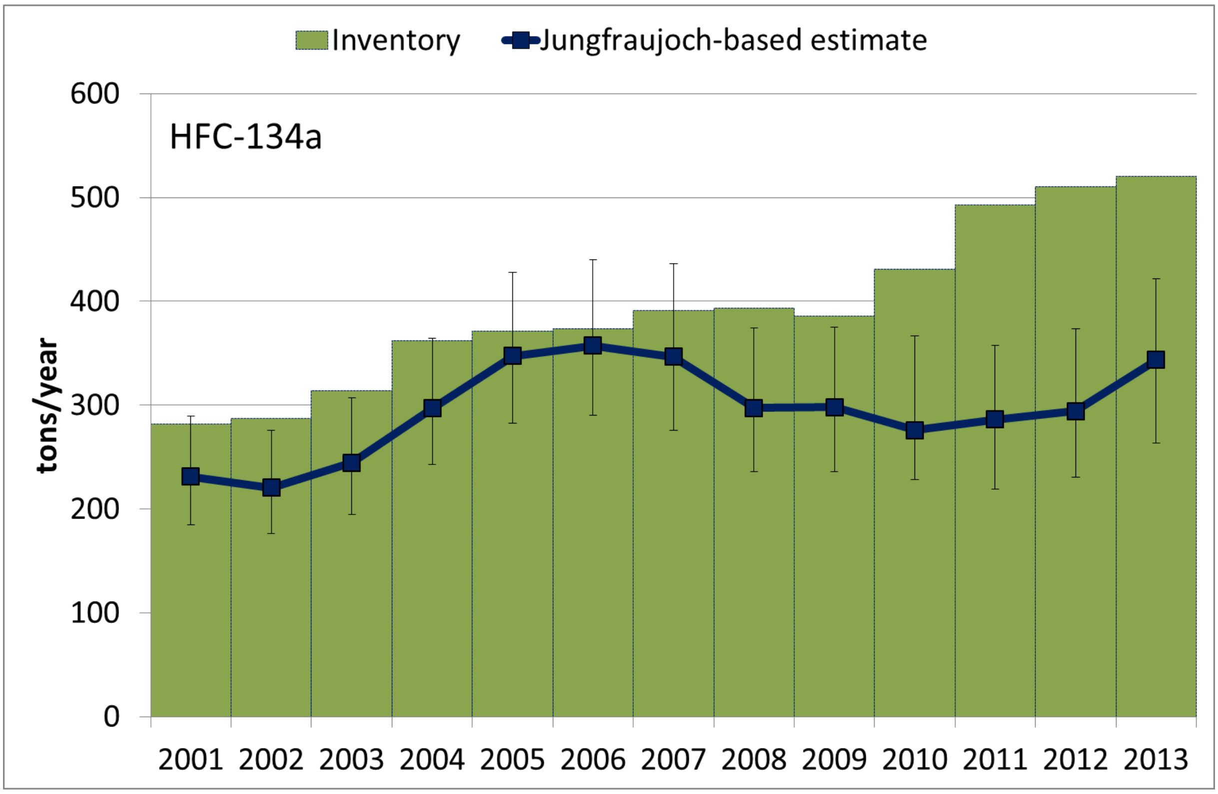


Figure A – 4 Comparison of HFC-134a emissions from Switzerland: Inventory and estimates from measurements at Jungfraujoch.

HFC-125

HFC-125 is mainly used as cooling agent in air conditioners and commercial refrigeration equipment. Estimated emissions from Jungfraujoch measurement data are in fairly good agreement with emissions provided by the inventory. Although, in recent years, the inventory emissions seem to slightly exceed the estimates based on data from Jungfraujoch.

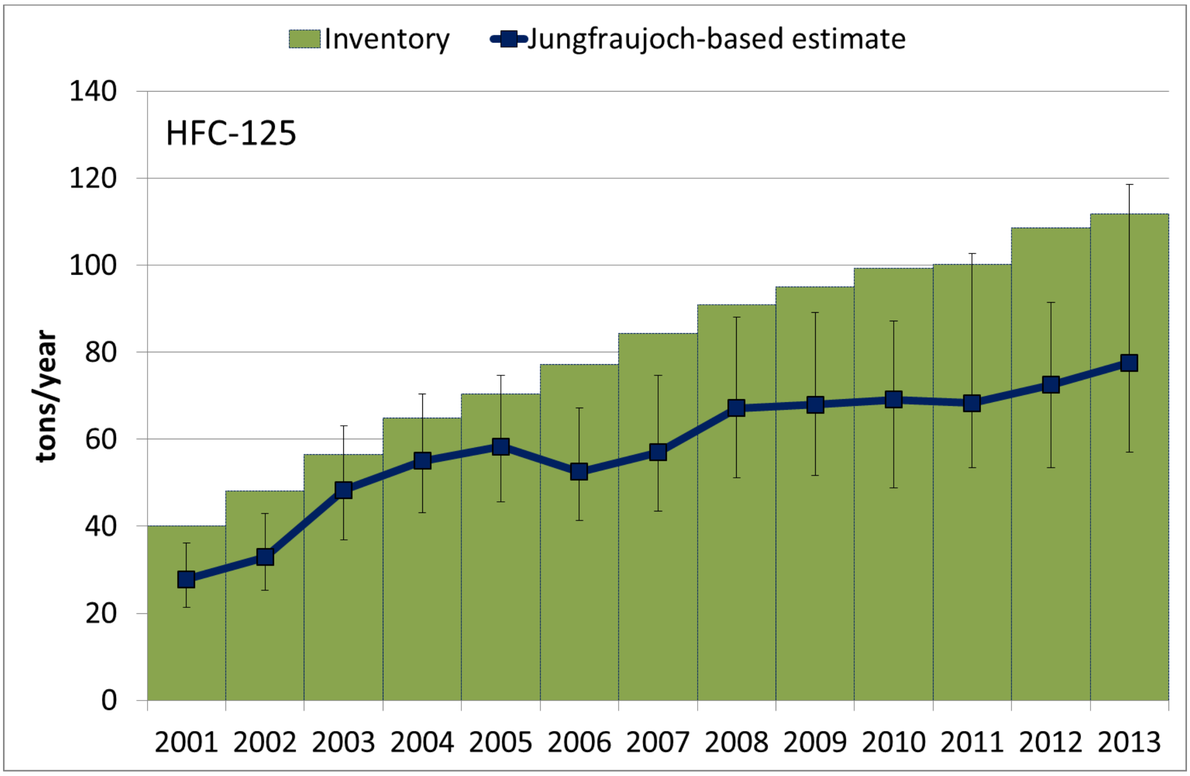


Figure A – 5 Comparison of HFC-125 emissions from Switzerland: Inventory and estimates from measurements at Jungfraujoch.

HFC-152a

HFC-152a is mainly used as a blowing agent. It has been used in open-cell polyurethane (PU) foams, in closed cell PU-Sprays and closed-cell extruded polystyrene (XPS) foams. In open cell foams, 100% of emissions are related to the blowing process. In closed cell foams a portion of the blowing agent remains in the product, emissions occur continuously over the lifetime, depending on the cell- and molecular-structure of the blowing agent. Unlike for other blowing agents, experts assume that within the first year of the foam lifetime 95-100% of HFC-152a is emitted. The emissions of the first year are commonly allocated to the country of production (according to UNFCCC good practice guidance). These assumptions and allocation are also applied for the model used in the Swiss inventory for estimating HFC-152a emissions under source category 2F2 Foam Blowing.

HFC-152a emissions from foams in the inventory are mainly related to the production and consumption of PU-Spray. Most of other foam products are imported and consequently these emissions are allocated to the country of origin. The reported decrease in the inventory since 2003 reflects the replacement of HFC-152a in PU-Spray.

Up to the year 2002 estimated emissions from Jungfraujoch measurement data are lower than reported in the inventory and from then onwards they are higher. This can be explained by the UNFCCC practice to allocate HFC-152a emissions of the first year to the country of production of foams (which is except for PU-Spray mainly outside Switzerland). However, in reality a fraction of these first year emissions actually occur during usage of the products (e.g. for insulation) in Switzerland and therefore are reflected in the measurements but are not reflected by definition in the inventory[15]. Emissions estimated from Jungfraujoch show a consistent negative trend related to the partial phase-out of HFC-152a from the foam-blowing applications.

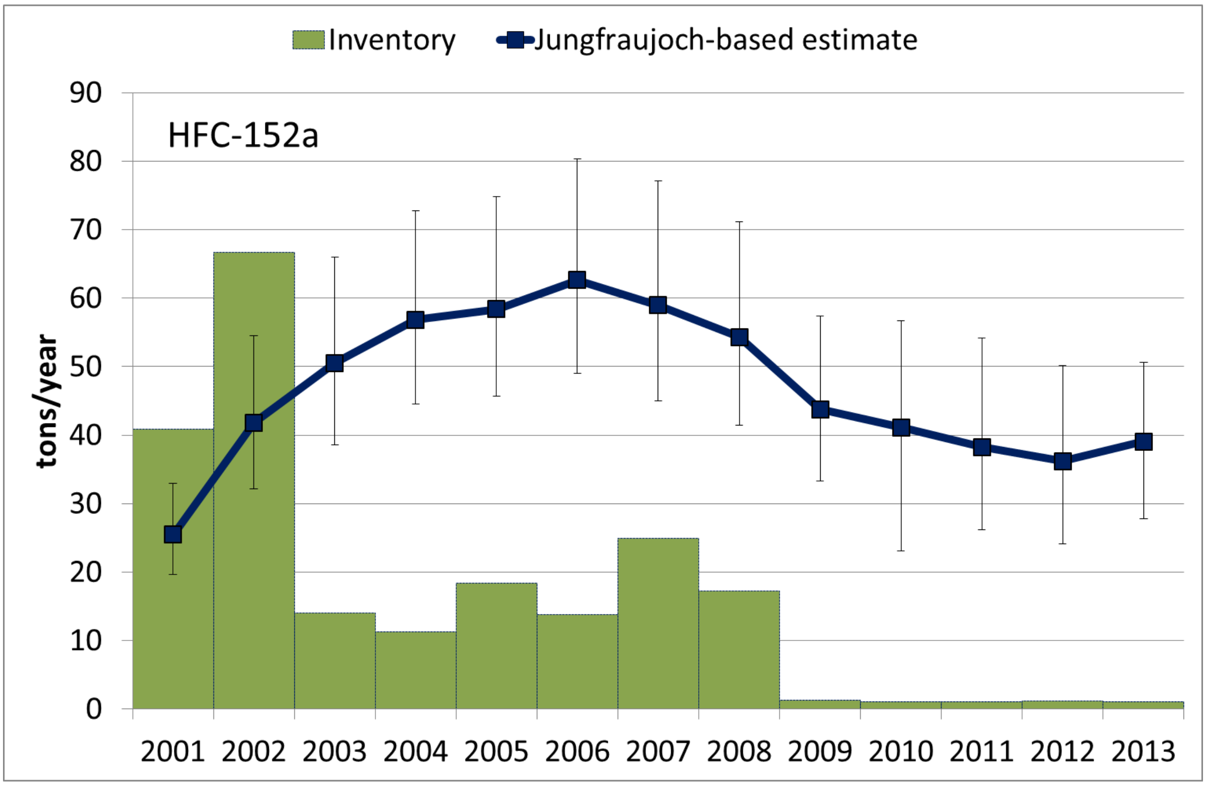


Figure A – 6 Comparison of HFC-152a emissions from Switzerland: Inventory and estimates from measurements at Jungfraujoch.

HFC-143a and HFC-32

HFC-143a and HFC-32 are mainly used as cooling agent mixtures in commercial refrigeration and stationary air conditioners (together with HFC-134a and/or HFC-125). Estimated emissions from Jungfraujoch measurement data are consistently slightly lower than emissions provided by the inventory. However, they normally agree within the uncertainty of 40% reached for these two compounds by the Jungfraujoch-based estimates.

[15] Nonetheless it is important to apply the UNFCCC approach in the inventory as otherwise double counting may occur when allocating the total emissions to the country of origin and the country of product use.

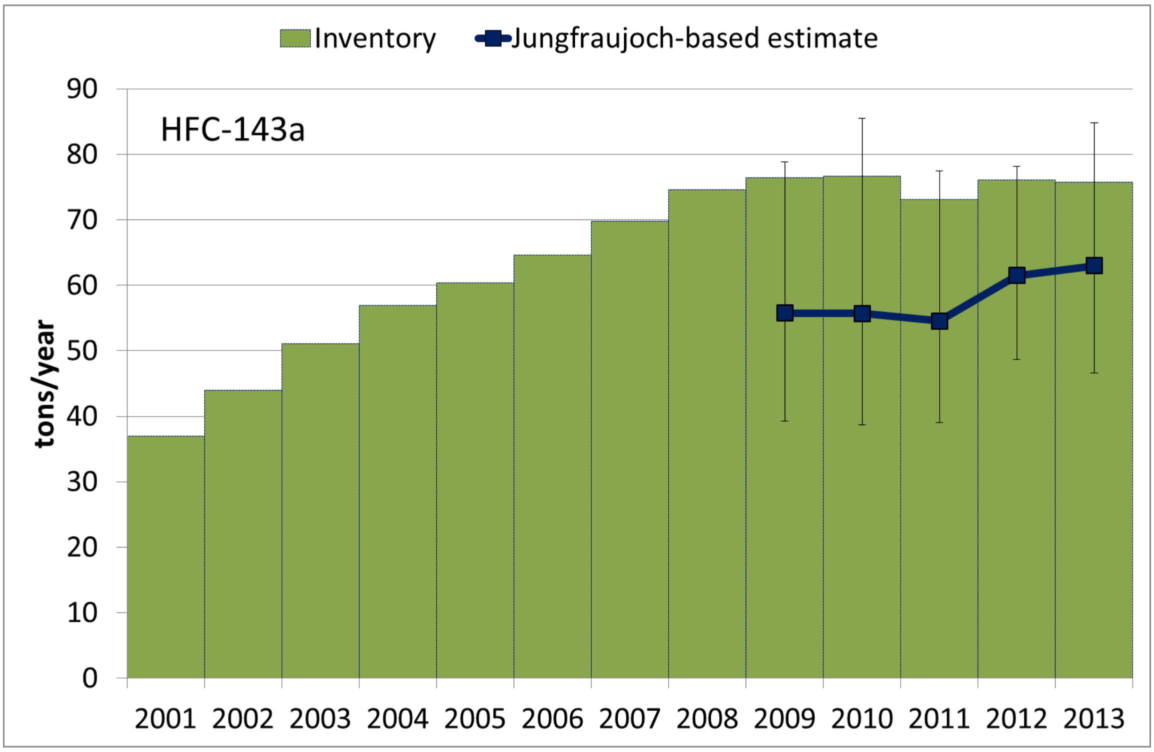


Figure A – 7 Comparison of HFC-143a emissions from Switzerland: Inventory and estimates from measurements at Jungfraujoch.

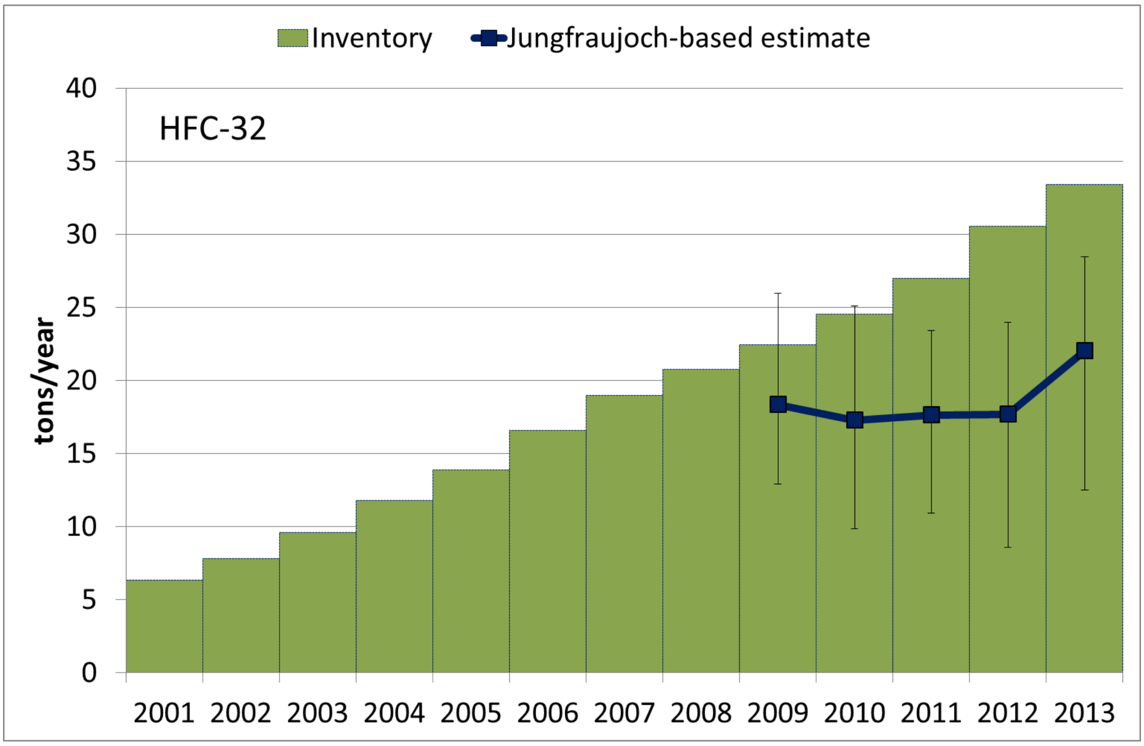


Figure A – 8 Comparison of HFC-32 emissions from Switzerland: Inventory and estimates from measurements at Jungfraujoch.

Sulfur hexafluoride (SF_6)

Emissions of SF_6 in Switzerland are mainly due to its use as an insulator of electrical equipment as for example gas insulated switchgears and gas circuit breakers. Minor emissions arise from magnesium smelters and its former use for insulating windows and various other applications. Emissions for both methods show a remarkable similarity in the trend, except for the period of 2001-2003, with slightly higher emissions estimated from the measurement-based method. Data quality of the inventory has been improved in this periode, since 2003 a mass balance approach based on industry data is applied for the unse of SF_6 in electrical equipment.

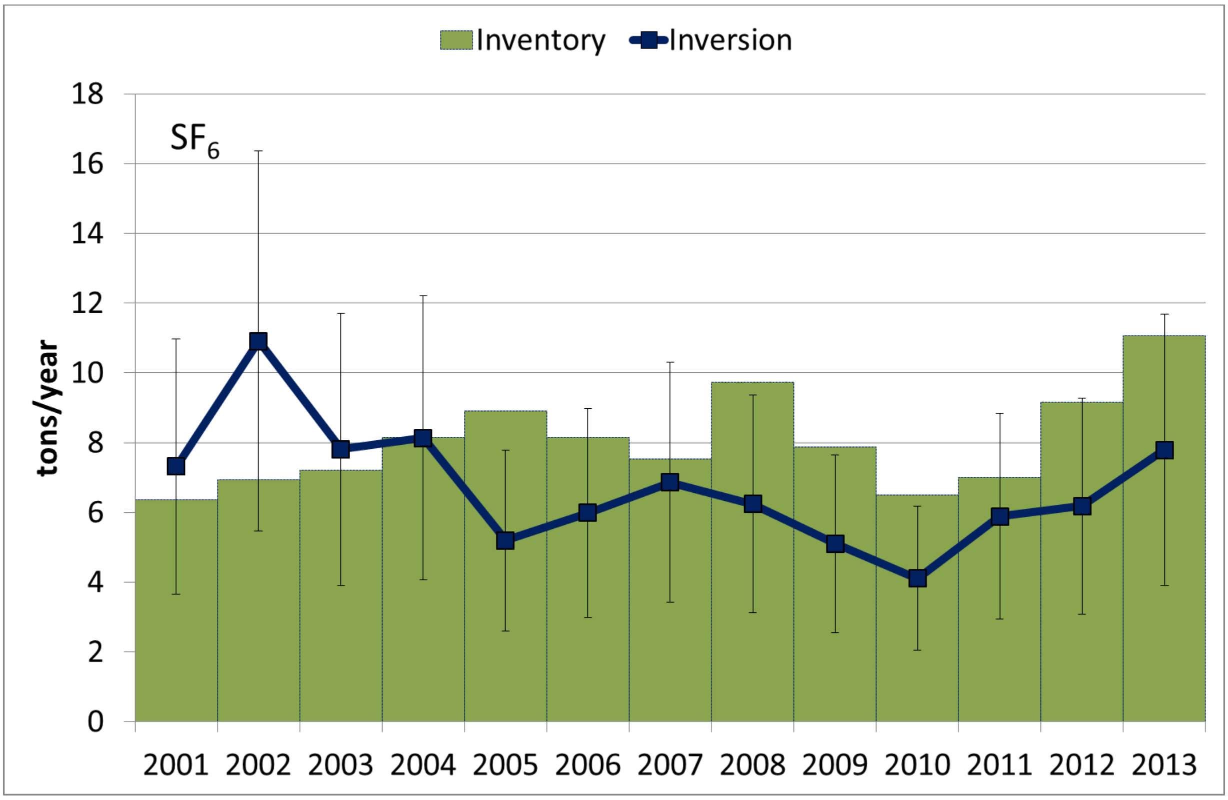


Figure A – 9 Comparison of SF_6 emissions from Switzerland: Inventory and estimates from measurements at Jungfraujoch.

References

Abegg, M., Brändli, U.-B., Cioldi, F., Fischer, C., Herold-Bonardi, A., Huber, M., Keller, M., Meile, R., Rösler, E., Speich, S., Traub, B., Vidondo, B. 2014. Fourth national forest inventory - result tables and maps on the Internet for the NFI 2009-2013 (NFI 4b). Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf. http://www.lfi.ch/resultate/ [16.06.2014]

ACW/ART 1998: Bestimmung des organisch gebundenen Kohlenstoffs (Corg). [Determination of soil organic carbon]. Referenzmethoden der Forschungsanstalten Agroscope. Band 1: Bodenuntersuchung zur Düngeberatung. Agroscope Changins-Wädenswil Research Station, Nyon & Wädenswil and Agroscope Reckenholz-Tänikon Research Station, Zürich. Version 01.02.1998. http://www.bafu.admin.ch/ghginv-ref

Agrammon 2010: The Swiss ammonia model, Federal Office for the Environment FOEN. Internet version in German, French and English: http://www.agrammon.ch/documents-to-download/ [28.02.2014]
Technical description for download (updated periodically): http://www.agrammon.ch/technical-description [28.02.2014]

Agricura 2014: Geschäftsbericht 2013/2014. Agricura, Bern.

Agroscope 2014a: Lime application in Swiss Agriculture. Internal documentation by Bretscher, D., Agroscope Reckenholz-Tänikon Research Station, Zürich. http://www.bafu.admin.ch/ghginv-ref

Agroscope 2014b: Futtermitteldatenbank. Agroscope, Institut für Nutztierwissenschaften (INT). Posieux, Schweiz. http://www.feedbase.ch [26.02.2015]

Agroscope 2014c: Fütterungstool zur Ermittlung des Energie- und Stickstoffumsatzes von Milchkühen in der Schweiz. Agroscope, Institut für Nutztierwissenschaften (INT). Posieux, Schweiz.

Agroscope 2015: Treibhausgasinventar Sektor Landwirtschaft, Tabellen zur Berechnung der Treibhausgasemissionen der schweizerischen Landwirtschaft. Internes Dokument. [GHG inventory, sector Agriculture. Spreadsheets to calculate the GHG emissions of Switzerland's agriculture. Internal document]. Agroscope Reckenholz-Tänikon Research Station, Zürich. http://www.bafu.admin.ch/ghginv-CP2-ref

Alberti, G., Peressotti, A., Piussi, P., Zerbi, G. 2008: Forest ecosystem carbon accumulation during a secondary succession in the Eastern Prealps of Italy. Forestry 81: 1-11. http://dx.doi.org/10.1093/forestry/cpm026 [26.02.2015]

Alcan 2002: Written communication from Kurt Buxmann (ALCAN) to Carbotech (confidential), 30.1.2002.

Alcan 2003: Written communication from François Veuthey (ALCAN) to Carbotech (confidential).

Altwegg, J., Schoop, A., Hofer, P. 2010: Klären von Differenzen zwischen Holznutzungsmengen nach Forststatistik und nach LFI. Technischer Bericht Im Auftrag des Bundes-amtes für Umwelt (BAFU). 82 p. http://www.bafu.admin.ch/wald/01234/11652/index.html?lang=de

Amon, B., Amon, T., Boxberger, J., Alt, C. 2001: Emissions of NH3, N_2O and CH_4 from dairy cows housed in a farmyard manure tying stall (housing, manure storage, manure spreading). Nutrient Cycling in Agroecosystems 60 (1-3): 103-113.

Andreani-Aksoyoglu, S., Keller, J. 1995: Estimates of monoterpene and isoprene emissions from the forests in Switzerland. Journal of Atmospheric Chemistry 20: 71-87. http://dx.doi.org/10.1007/BF01099919 [26.02.2015]

ARE 2002: Fahrleistungen der Schweizer Fahrzeuge. Ergebnisse der periodischen Erhebung Fahrleistungen (PEFA) 2000. Federal Office for Spatial Development, Bern. http://www.bafu.admin.ch/ghginv-ref

ARE 2010: Nationales Personenverkehrsmodell – Basismodell 2005, Bern. http://www.are.admin.ch/dienstleistungen/00906/index.html?lang=de [20.01.2015]

ARE 2012: Ergänzungen zu den schweizerischen Verkehrsperspektiven bis 2030. Bundesamt für Raumentwicklung (ARE). Bern http://www.are.admin.ch/dokumentation/publikationen/00015/00471/index.html?lang=de [19.01.2015]

ARE/SAEFL 2001: Le paysage sous pression, suite 2. [Landschaft unter Druck, 2. Fortschreibung]. Federal Office for Spatial Development, Bern and Swiss Agency for the Environment, Forests and Landscape, Bern. http://www.are.admin.ch/themen/raumplanung/00246/03637/index.html?lang=fr [28.02.2014]

ARE/SFSO 2005: Mobilität in der Schweiz. Ergebnisse des Mikrozensus 2005 zum Verkehrsverhalten. [La mobilité en Suisse. Résultats du microrecensement 2005 sur le comportement de la population en matière de transports]. Federal Office for Spatial Development, Bern and Swiss Federal Statistical Office, Neuchâtel.
http://www.bfs.admin.ch/bfs/portal/de/index.Document.91826.pdf [German] [20.01.2015]
http://www.bfs.admin.ch/bfs/portal/fr/index.Document.91826.pdf [French] [20.01.2015]

ART 2008a: Uncertainty in agricultural CH_4 and N_2O emissions of Switzerland. Internal documentation by Bretscher, D. and Leifeld, J., Agroscope Reckenholz-Tänikon Research Station, Zürich.
http://www.bafu.admin.ch/ghginv-ref

ART 2009b: Emission factor drained peatlands Switzerland – A brief analysis of recent studies and comparison to EF used in the Swiss GHG Inventory. Internal documentation by Leifeld, J., Agroscope Reckenholz-Tänikon Research Station, Zürich.
http://www.bafu.admin.ch/ghginv-ref

ART 2011a: Summary of the available published data on root biomass and root carbon in Swiss grasslands. Internal documentation by Leifeld, J., Agroscope Reckenholz-Tänikon Research Station, Zürich.
http://www.bafu.admin.ch/ghginv-ref

ART 2011b: First estimate on CO_2 emission factor of organic soils under unproductive wetland. Internal documentation by Leifeld, J., Agroscope Reckenholz-Tänikon Research Station, Zürich.
http://www.bafu.admin.ch/ghginv-ref

ART 2012a: Carbon in Living Biomass and Dead Organic Matter in Croplands and Grasslands: Current state of the Swiss GHG-Inventory. Internal documentation by Bretscher, D., Agroscope Reckenholz-Tänikon Research Station, Zürich.

ART 2013a: Agricultural CH_4 and N_2O emissions in Switzerland: QA/QC. Internal documentation (with continual update) by Bretscher, D., Agroscope Reckenholz-Tänikon Research Station, Zürich.
http://www.bafu.admin.ch/ghginv-ref

ART/SHL 2012: Categorization of livestock animals in Switzerland. D. Bretscher and T. Kupper. Agroscope Research Station Zürich (ART), Schweizerische Hochschule für Landwirtschaft Zollikofen (SHL). March 2012.
http://www.bafu.admin.ch/ghginv-ref

Bader, M.K., Leuzinger, S., Keel, S.G., Siegwolf, T.W., Hagedorn, F., Schleppi, P., Körner, C. 2013: Central European hardwood trees in a high-CO_2 future: synthesis of an 8-year forest canopy CO_2 enrichment project. Journal of Ecology 101 (6): 1509–1519.
http://onlinelibrary.wiley.com/doi/10.1111/1365-2745.12149/abstract

Battelle 1994: Methanfreisetzung bei der Erdgasnutzung in der Schweiz und Vergleich mit anderen Emittenten. Studie im Auftrag des Schweizerischen Vereins des Gas- und Wasserfaches SVGW. Battelle Ingenieurtechnik, GmbH, Eschborn.
http://www.bafu.admin.ch/ghginv-ref

Brändli, U.-B. (Red.) 2010: Schweizerisches Landesforstinventar. Ergebnisse der dritten Aufnahme 2004-2006. [Results of the third Swiss national forest inventory 2004-2006]. Eidgenössische Forschungsanstalt für Wald, Schnee und Landschaft, Birmensdorf. Bundesamt für Umwelt, Bern, 312 S.
http://www.lfi.ch/publikationen/publ/lfi3-fr.php [18.03.2014]

Brändli, U.-B., Speich, S. 2011: Das LFI4 – eine kontinuierliche Erhebung. LFI-News 13.
http://www.lfi.ch/publikationen/publ/lfi-info/LFIinfo13.pdf [04.04.2014]

Brändli, U.-B. (2014): Mehr Laubbäume und weniger Fichtenholz im Mittelland. Medienmitteilung 06.11.2014, Birmensdorf.
http://www.wsl.ch/medien/news/landesforstinventar_2014/index_DE

Brassel, P., Brändli, U.-B. 1999: Schweizerisches Landesforstinventar. Ergebnisse der Zweitaufnahme 1993-1995. [Results of the second Swiss national forest inventory 1993-1995]. Eidgenössische Forschungsanstalt für Wald, Schnee und Landschaft, Birmensdorf. Bundesamt für Umwelt, Wald und Landschaft, Bern. Haupt, Bern, Stuttgart, Wien. [available in German, French and Italian]
http://www.lfi.ch/publikationen/publ/lfi2-en.php [18.03.2014]

Braun, S., Thomas, V.F., Quiring, R., Flückiger, W. 2010: Does nitrogen deposition increase forest production? The role of phosphorus. Environmental Pollution 158(6): 2043-2052.
http://dx.doi.org/10.1016/j.envpol.2009.11.030

Bühlmann, T., Hiltbrunner, E., Körner, Ch., Rihm, B., Achermann, B. 2015: Induction of indirect N_2O and NO emissions by atmospheric nitrogen deposition in (semi-)natural ecosystems in Switzerland. Atmospheric Environment 103(0): 94-101.

Bühlmann, T. 2014: Durch Stickstoffdeposition induzierte Emissionen von Stickoxiden und Lachgas aus (semi-)natürlichen Ökosystemen. Analyse der schweizerischen Situation mit Vorschlägen zur Umsetzung im Schweizerischen Emissionsinventar (EMIS). Bundesamt für Umwelt (BAFU), Juli 2014. Bern; Schweiz.

BUS 1986: Leitbild für die Schweizerische Abfallwirtschaft. [Lignes directrices pour la gestion des déchets en Suisse]. Schriftenreihe Umweltschutz Nr. 51. Bundesamt für Umweltschutz BUS. [Les cahiers de l'environnement No 51. Office fédéral de la protection de l' environnement], Bern.
http://www.bafu.admin.ch/ghginv-ref

Carbotech 2015: Swiss Greenhouse Gas Inventory 2013: PFCs, HFCs, NF3 and SF6 Emissions. Confidential report no. 251.16. For internal use on behalf of the Federal Office for the Environment, Bern. Basel.

Carbotech 2014a: CO_2 aus VOC-Verbrennung Confidential report no. 129.15. For internal use on behalf of the Federal Office for the Environment, Bern. Basel.

CARBURA 2010: Bunkers of diesel oil 1990-2009. Written communication from Matthias Rufer (CARBURA) to Jan Landert (INFRAS), 17.12.2010.
http://www.bafu.admin.ch/ghginv-ref

Cemsuisse 2010a: Bestimmung der Emissionsfaktoren an Mischproben, Interner Bericht von Wessling im Auftrag von cemsuisse, 2010

Cemsuisse 2014: Jahresbericht 2013. [Rapport annuel 2013]. Association of the Swiss Cement Industry, Bern.
http://www.cemsuisse.ch/php/modules/mediamanager/sendobject.php?lang=de&download=NHzLpZeg7t,lnJ6IzdeIp96km56VlWtvl5ROqdayYLGH4tjTy4am06iDf76Af4SN0NTY0oau3aWWpI3Iy5Wn6A-- [German and French] [25.03.2015]

CH2011 2011: Swiss Climate Change Scenarios CH2011. Published by C2SM, MeteoSwiss, ETH, NCCR Climate, and OcCC, Zurich, Switzerland: 1-88.
http://www.ch2011.ch/ [27.11.2014]

Covington, W.W. 1981: Changes in forest floor organic matter and nutrient content following clear cutting in northern hardwoods. Ecology 62(1): 41-48.
http://www.jstor.org/pss/1936666 [28.02.2013]

Cronan, C.S. 2003: Belowground biomass, production, and carbon cycling in mature Norway spruce, Maine, U.S.A. Canadian Journal of Forest Research 33: 339-350.
http://dx.doi.org/10.1139/x02-189

Crutzen, P.J., Aselmann, I., Seiler, W. 1986: Methane production by domestic animals, wild ruminants, other herbivorous fauna, and humans. Tellus 38B(3-4): 271-284.

CSD 2013: Swiss Greenhouse Gas Inventory Submission 2012. National Review of Sector Industrial Processes. On behalf of the Federal Office for the Environment, Bern. Basel
http://www.bafu.admin.ch/ghginv-ref

Davidson, E.A., Janssens, I.A. 2006: Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. Nature 440: 165-173.
http://dx.doi.org/10.1038/nature04514

DDPS 2014: Consumption of aviation fuel and jet kerosene of Swiss military aircraft 1990-2013. Didier Castella (VBS, Raum und Umwelt) to Anouk-Aimée Bass (FOEN, Bern),
http://www.bafu.admin.ch/ghginv-CP2-ref

de Keizer, C., Ramirez, A., van der Sluijs, J. 2007: Uncertainty Ranges and Correlations Assumed in Tier 2 Studies of Several European Countries. In: Proceedings of the 2nd International Workshop on Uncertainties in Greenhouse Gas Inventories, 27-28 September

2007, Laxenburg, Austria: 35-39.
http://www.ibspan.waw.pl/ghg2007/GHG-total.pdf [24.02.2015]

DelSontro, T., McGinnis, D. F., Sobek, S., Ostrovsky, I., Wehrli, B. 2010: Extreme methane emissions from a Swiss hydropower reservoir: contribution from bubbling sediments, Environmental Science & Technology 44: 2419-2425.
http://dx.doi.org/10.1021/es9031369

Didion, M., Kaufmann, E., Thürig, E. 2012: Estimation of carbon stocks and stock changes in soil, LFH layer and deadwood in Swiss forests with Yasso07. Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf. Commissioned by the Federal Office for the Environment FOEN, Bern.
http://www.bafu.admin.ch/ghginv-ref

Didion, M., Kaufmann, E., Thürig, E. 2013: Data on soil carbon stock change, carbon stock and stock change in surface litter and in coarse deadwood prepared for the Swiss GHGI 1990-2012. Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf. Commissioned by the Federal Office for the Environment FOEN, Bern.

Didion, M. 2014: Impacts of forest management on carbon stock changes in litter and soil in Swiss forests. Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf. Commissioned by the Federal Office for the Environment FOEN, Bern.
http://www.bafu.admin.ch/ghginv-ref

Didion, M., Kaufmann, E., Thürig, E. 2014: Data on soil carbon stock change, carbon stock and stock change in surface litter and in coarse deadwood prepared for the Swiss GHGI 2015 (1990-2013). Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf. Commissioned by the Federal Office for the Environment FOEN, Bern.
http://www.bafu.admin.ch/ghginv-CP2-ref [26.02.2015]

Didion, M., Rogiers, N., Frey, B., Thürig, E. 2014a: Validating tree litter decomposition in the Yasso07 carbon model. Ecological Modelling 291: 58–68.
doi:10.1016/j.ecolmodel.2014.07.028. http://www.bafu.admin.ch/ghginv-CP2-ref

Didion, M., Kaufmann, E., Thürig, E. 2014b: Estimating carbon stock changes in living and dead biomass and soil for Switzerland's Forest Management Reference Level – modeling methodology and results. Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf. Commissioned by the Federal Office for the Environment FOEN, Bern.
http://www.bafu.admin.ch/ghginv-CP2-ref

Dobbertin, M., Jüngling, E. 2009: Totholzverwitterung und C-Gehalt. Zwischenergebnisse. [Wood density and carbon content with changing degree of dead wood decay: First results]. Swiss Federal Research Institute for Forest, Snow and Landscape Research, Birmensdorf.
http://www.bafu.admin.ch/ghginv-ref

Düggelin, C., Abegg, M. 2011: Modelle zur Biomasse- und Holzvolumenschätzung im Schweizer Gebüschwald. Schweizerische Zeitschrift für Forstwesen 162 (2): 32-40.
http://dx.doi.org/10.3188/szf.2011.0032

EAFV (Eidg. Anstalt für das forstliche Versuchswesen) / BFL (Bundesamt für Forstwesen und Landschaftsschutz) (eds.) 1988: Schweizerisches Landesforstinventar. Ergebnisse der Erstaufnahme 1982-1986. [Results of the first Swiss national forest inventory 1982-1986]. Ber. Eidgenöss. Forsch.anst. Wald Schnee Landsch. 305.
http://www.lfi.ch/publikationen/publ/lfi1-en/php [13.03.2013]

EMEP/EEA 2002: EMEP/CORINAIR Emission Inventory Guidebook. European Environment Agency. 3rd edition October 2002 update.
http://www.eea.europa.eu/publications/EMEPCORINAIR3/page002.html [28.01.2014]

EMEP/EEA 2010: EMEP/EEA Emission Inventory Guidebook 2009, updated June 2010, Methodology for the calculation of exhaust emissions – SNAPs 070100-070500, NFRs 1A3bi-iv Passenger cars, light-duty trucks, heavy-duty vehicles including buses and motor cycles.
http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009 [28.02.2014]

EMEP/EEA 2013: Air Pollutant Emission Inventory Guidebook 2013, European Environment Agency.
http://www.eea.europa.eu/publications/emep-eea-guidebook-2013 [29.01.2014]

EMIS 2015/(NFR-Code): Comments to EMIS database. Internal documents. Federal Office for the Environment, Bern.
To find the EMIS comment that belongs to the specified NFR Code, see Table A - 1 (below References) [available in German, partly in English]

EMPA 1999: Written communication from Dr. H.W. Jäckle (EMPA, Dübendorf) to Andreas Liechti (FOEN, Bern), 09.03.1999.
http://www.bafu.admin.ch/ghginv-ref

EMPA 2004: EMPA Research Report 202114b. Swiss Laboratories for Material Science and Technology, Dübendorf.
http://www.bafu.admin.ch/ghginv-ref

EMPA 2004a: Baustoffmanagement 21. Stand des Wissens und Forschungsbedarf.
http://www.bollinger.info/Rezension_Baustm21.pdf [26.02.2015]

Estermann, B. L., Wettstein, H.-R., Sutter, F., Kreuzer, M. 2001: Nutrient and energy conversion of grass-fed dairy and suckler beef cattle kept indoors and on high altitude pasture. Animal Research 50(6): 477-493.

Etzold, S., Ruehr, N.K., Zweifel, R., Dobbertin, M., Zingg, A., Pluess, P., Häsler, R., Eugster, W. Buchmann, N. 2011: The Carbon Balance of Two Contrasting Mountain Forest Ecosystems in Switzerland: Similar Annual Trends, but Seasonal Differences. Ecosystems 14: 1289–1309.
http://dx.doi.org/10.1007/s10021-011-9481-3
http://www.natkon.ch/pdf_files/publikationsseite/Etzold_etal_2011_Ecosystems.pdf [28.02.2013]

EV 2014: Jahresbericht 2013. Erdöl-Vereinigung [Rapports annuel 2013. L'Union Pétrolière]. Zürich.
http://www.erdoel-vereinigung.ch/UserContent/Shop/EV_Jahresbericht_2013_D_WEB.pdf, in German [06.11.2014]

Falloon, P., Smith, P. 2003: Accounting for changes in soil carbon under the Kyoto protocol: need for improved long-term data sets to reduce uncertainty in model projections. Soil Use and Management 19(3): 265-269.
http://dx.doi.org/10.1079/SUM2003201

FAL/RAC 2001: Grundlagen für die Düngung im Acker- und Futterbau 2001. [Principles of fertilization in crop and feed production]. Eidgenössische Forschungsanstalt für

Agrarökologie und Landbau / Eidgenössische Forschungsanstalt für Pflanzenbau, Agrarforschung, June 2001, Zürich-Reckenholz, Nyon. [available in German and French] http://www.bafu.admin.ch/ghginv-ref

FEDPOL 2014: Bundesamt für Polizei fedpol, Fedpol-Statistik 2014 https://www.fedpol.admin.ch/fedpol/de/home.html [26.02.2015]

FEDRO 2010: Swiss Automatic Road Traffic Counts (SARTC). Federal Roads Office, Bern. http://www.astra.admin.ch/verkehrsdaten/00299/00301/index.html?lang=en [20.01.2015]

Fernández, C., Espinós, F.J., López, M.C., García-Diego, F.J., Cervera, C. 2013: Representation of a mathematical model to predict methane output in dairy goats. Computers and Electronics in Agriculture 91(0): 1-9.

Fial 2013: Die Schweizer Nahrungsmittel-Industrie im Jahr 2012. http://fial.ch/de/statistics/fial_Statistik%202012_de.pdf [16.01.2015]

Fischer, C., P. Camin, E. Kaufmann,Thürig, E. 2015. National woody biomass scenario methods for Switzerland based on National Forest Inventory data. In: Barreiro, S., Kaendler, G., McRoberts, R.E., Schelhaas, M.-J. (eds). Managing Forest Ecosystem: Wood and Biomass Projection Systems Using National Forest Inventory Data [forthcoming]. Springer.

Flisch, R., Sinaj, S., Charles, R., Richner, W. 2009: Grundlagen für die Düngung im Acker- und Futterbau 2009. Forschungsanstalt Agroscope Changins-Wädenswil ACW und Agroscope Reckenholz-Tänikon ART, Agrarforschung 16 (2).

FOCA 1991: Crossair confidential data 1991. Federal Office of Civil Aviation, Bern.

FOCA 1991a: L'aviation civile Suisse en 1990. Federal Office of Civil Aviation, Bern. http://www.bafu.admin.ch/ghginv-ref

FOCA 2004: Unternehmensstatistik der Schweizerischen Helikopterunternehmungen. Federal Office of Civil Aviation, Bern. http://www.bafu.admin.ch/ghginv-ref

FOCA 2006: GHG emissions of Swiss civil aircraft in 1990 and 2004: data, proceeding and description of the calculations. Written communication from Theo Rindlisbacher and Paul Stulz (FOCA, Bern) to Andreas Liechti (FOEN, Bern), 20./22.02.2006. http://www.bafu.admin.ch/ghginv-ref

FOCA 2006a: GHG emissions of Swiss civil aircraft in 1990, 1995, 2000, 2002, 2004 and 2005: data, proceeding and description of the calculations. Written communication from Theo Rindlisbacher (FOCA, Bern) to Paul Filliger (FOEN, Bern), 17.11.2006. http://www.bafu.admin.ch/ghginv-ref

FOCA 2007: GHG emissions of Swiss civil aircraft in 2006. Written communication from Theo Rindlisbacher (FOCA, Bern) to Beat Müller (FOEN, Bern), 03.12.2007. http://www.bafu.admin.ch/ghginv-ref

FOCA 2007a: Aircraft Piston Engine Emissions. Summary Report. Federal Office of Civil Aviation. Report Ref. 0 / 3/33/33-05-003 ECERT. Bern. http://www.bafu.admin.ch/ghginv-ref

FOCA 2007b: Validation of ADAECAM (Advanced Aircraft Emission Calculation Method). Report on fuel calculation. Federal Office of Civil Aviation. Report Ref. 0/3/33/33-05-007.021.

Bern, 10.08.2007.
http://www.bafu.admin.ch/ghginv-ref

FOCA 2008: GHG emissions of Swiss civil aircraft in 2007. Written communication from Theo Rindlisbacher (FOCA, Bern) to Beat Müller (FOEN, Bern), 01.12.2008.
http://www.bafu.admin.ch/ghginv-ref

FOCA 2009: GHG emissions of Swiss civil aircraft in 2008. Written communication from Theo Rindlisbacher (FOCA, Bern) to Beat Müller (FOEN, Bern), 04.11.2009.
http://www.bafu.admin.ch/ghginv-ref

FOCA 2009a: Guidance on the determination of helicopter emissions. Federal Office of Civil Aviation. Report Ref. 0/3/33/ 33-05-020. Edition 1. Bern. March 2009
http://www.bafu.admin.ch/ghginv-ref

FOCA 2010: GHG emissions of Swiss civil aircraft in 2009. Written communication from Theo Rindlisbacher (FOCA, Bern) to Sophie Hoehn (FOEN, Bern), 18.11.2010.
http://www.bafu.admin.ch/ghginv-ref

FOCA 2011: GHG emissions of Swiss civil aircraft in 2010. Written communication from Theo Rindlisbacher (FOCA, Bern) to Sopie Hoehn (FOEN, Bern), 09.11.2011.
http://www.bafu.admin.ch/ghginv-ref

FOCA 2012: GHG emissions of Swiss civil aircraft in 2011. Written communication from Theo Rindlisbacher (FOCA, Bern) to Anouk-Aimée Bass (FOEN, Bern), 07.09.2012.
http://www.bafu.admin.ch/ghginv-ref

FOCA 2013: GHG emissions of Swiss civil aircraft in 2012. Written communication from Theo Rindlisbacher (FOCA, Bern) to Anouk-Aimée Bass (FOEN, Bern), 07.11.2013.
http://www.bafu.admin.ch/ghginv-CP2-ref

FOCA 2014: GHG emissions of Swiss civil aircraft in 2013 and corrections for the year 2011. Written communication from Theo Rindlisbacher (FOCA, Bern) to Anouk-Aimée Bass (FOEN, Bern), 30.10.2014.
http://www.bafu.admin.ch/ghginv-CP2-ref

FOEN 2006h: Switzerland's Initial Report under Article 7, paragraph 4 of the Kyoto Protocol. Federal Office for the Environment, Bern. Including the Update following the UNFCCC review (FCCC/IRR/2007/CHE).
http://www.bafu.admin.ch/ghginv-CP1-IR

FOEN 2008: Switzerland's Greenhouse Gas Inventory 1990–2006, National Inventory Report and CRF-tables 2008. Submission of 15 April 2008 under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol. Federal Office for the Environment, Bern.
http://www.bafu.admin.ch/ghginv2008 [27.02.2015]

FOEN 2008h: Wood Resource Policy: Strategy, Objectives and Action Plan for the Resource Wood. Federal Office for the Environment, Bern.
http://www.bafu.admin.ch/publikationen/publikation/01002/index.html?lang=en [26.02.2015]

FOEN 2010d: Deforestations in Switzerland as reported under the Kyoto Protocol Art. 3.3. Forest Division, Federal Office for the Environment, Bern.
http://www.bafu.admin.ch/ghginv-ref

FOEN 2010h: Afforestations in Switzerland as reported under the Kyoto Protocol Art. 3.3. Forest Division, Federal Office for the Environment, Bern.
http://www.bafu.admin.ch/ghginv-ref

FOEN 2010i: Pollutant Emissions from Road Transport, 1990 to 2035. Updated in 2010. Environmental studies no. 1021. Federal Office for the Environment, Bern.
http://www.bafu.admin.ch/publikationen/publikation/01565/index.html?lang=en [10.01.2015]

FOEN 2010j: Abfallmengen und Recycling 2009 im Überblick. [Overview on waste quantities and recycling in 2009.] Federal Office for the Environment, Bern.
http://www.bafu.admin.ch/abfall/01517/01519/10457/index.html?lang=de [26.02.2015]

FOEN 2011: Switzerland's Greenhouse Gas Inventory 1990–2009: National Inventory Report, CRF-tables, Kyoto Protocol LULUCF tables 2008-2009, SEF and SIAR tables from the National Registry. Submission of 15 April 2011 under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol. Federal Office for the Environment, Bern.
http://www.bafu.admin.ch/ghginv2011

FOEN 2011l: Switzerland's Submission on Reference Levels as an accounting approach for Forest Management under the Kyoto Protocol. Submission of 28 February 2011 under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol. Federal Office for the Environment, Bern.
http://unfccc.int/files/meetings/ad_hoc_working_groups/kp/application/pdf/awgkp_switzerland_2011.pdf [26.02.2015]

FOEN 2012: Switzerland's Greenhouse Gas Inventory 1990–2010: National Inventory Report, CRF-tables, Kyoto Protocol LULUCF tables 2008-2010, SEF and SIAR tables from the National Registry. Submission of 13 April 2012 under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol. Federal Office for the Environment, Bern.
http://www.bafu.admin.ch/ghginv2012

FOEN 2012b: Anpassung an den Klimawandel in der Schweiz – Ziele, Herausforderungen und Handlungsfelder. Erster Teil der Strategie des Bundesrates. Federal Office for the Environment. Bern.
http://www.bafu.admin.ch/klimaanpassung/11529 [27.11.2014]

FOEN 2012h: Adressliste der Schweizer Kläranlagen mit Angaben zur Ausbaugrösse. Swiss Federal Office of Energy, Bern.
http://www.bafu.admin.ch/gewaesserschutz/01295/01296/01298/index.html?lang=de [26.02.2015]

FOEN 2013: Switzerland's Greenhouse Gas Inventory 1990–2011: National Inventory Report, CRF-tables, Kyoto Protocol LULUCF tables 2008-2010, SEF and SIAR tables from the National Registry. Submission of April 2013 under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol. Federal Office for the Environment, Bern.
http://www.bafu.admin.ch/ghginv2013

FOEN 2013h: Abfallmengen und Recycling 2012 im Überblick. [Overview on waste quantities and recycling in 2010.] Federal Office for the Environment, Bern.
http://www.bafu.admin.ch/abfall/01517/01519/12949/index.html?lang=de [26.02.2015]

FOEN 2014: Switzerland's Greenhouse Gas Inventory 1990–2012: National Inventory Report, CRF-tables, Kyoto Protocol LULUCF tables 2008-2012, SEF and SIAR tables from the National Registry. Submission of 15 April 2014 under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol. Federal Office for the Environment, Bern.
http://www.bafu.admin.ch/ghginv2014

FOEN 2014d: Switzerland's Sixth National Communication under the UNFCCC; Third National Communication under the Kyoto Protocol to the UNFCCC. Federal Office for the Environment, Bern.
http://www.bafu.admin.ch/nc6 [26.02.2015]

FOEN 2014f: Illustration of unproductive forests in Switzerland. Internal report by the Swiss Federal Office for the Environment.
http://www.bafu.admin.ch/ghginv-ref

FOEN 2014h: Jahrbuch Wald und Holz 2014. Umwelt-Zustand Nr. 1332. [Annuaire La forêt et le bois 2014. Etat de l'environnement no 1420]. Federal Office for the Environment, Bern.
http://www.bafu.admin.ch/publikationen/publikation/01790/index.html?lang=de [German] [26.02.2015]
http://www.bafu.admin.ch/publikationen/publikation/01790/index.html?lang=fr [French] [26.02.2015]

FOEN 2014i: Hazardous Waste Statistics 2013. Various reports compiled by FOEN on its webite.
http://www.bafu.admin.ch/abfall/01517/01519/13508/index.html?lang=de [02.12.2014]

FOEN 2014j: Waste Statistics for 2013. Urban and Construction Waste Section, Federal Office for the Environment, Bern.
http://www.bafu.admin.ch/ghginv-CP2-ref (selected data)

FOEN 2014l: Kohlenstoffgehalt Abfall auf Basis des Heizwerts – Faktenblatt, FOEN, Bern. 31.10.2014.
http://www.bafu.admin.ch/ghginv-CP2-ref

FOEN 2014m: Switzerland's Greenhouse Gas Inventory 1990–2012. Resubmission in response to the centralized review: CRF-tables, Kyoto Protocol LULUCF table 2008-2012. Submission of November 2014 under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol. Federal Office for the Environment, Bern.
www.bafu.admin.ch/ghginv2014

FOEN 2014n: Standardmethode für Kompensationsprojekte des Typs „Landwirtschaftliche Biogasanlagen". Version für informelle Konsultation, 1.5.2014. Federal Office for the Environment, Geschäftsstelle Kompensation, Bern.

FOEN 2014o: Erhebung der Kehrichtzusammensetzung 2012. Federal Office for the Environment, Bern.
http://www.bafu.admin.ch/ghginv-CP2-ref

FOEN 2015a: Qualitätsmanagement Treibhausgasinventar – Handbuch. BAFU, Bern.

FOEN 2015b: Handbuch Berechnung der Wald-Emissionsfaktoren fürs Inventarjahr 2013 [Manual: Calculation of EFs for Forest Land]. Including 1 Excel data file. Internal document, Federal Office for the Environment, Bern.
http://www.bafu.admin.ch/ghginv-ref

FOEN 2015c: Handbuch Anleitung zum Ausfüllen der Kyoto Tabellen Wald 2013. [Instruction manual for completing data of forest related activities in Kyoto Tables]. Internal document, Federal Office for the Environment, Bern.

FOEN 2015d: Faktenblatt. CO2-Emissionsfaktoren des Treibhausgasinventars der Schweiz. Federal Office for the Environment, Bern.
http://www.bafu.admin.ch/ghginv-CP2-ref

FOEN 2015e: Switzerland's Second Initial Report under the Kyoto Protocol. Report to facilitate the calculation of the assigned amount pursuant to Article 3, paragraphs 7bis, 8 and 8bis, of the Kyoto Protocol for the second commitment period 2013–2020.
www.bafu.admin.ch/ghginv-CP2-IR

FOEN 2015f: Switzerland's Informative Inventory Report 2015 (IIR), Submission under the UNECE Convention on Long-range Transboundary Air Pollution, Submission of March 2015 to the United Nations ECE Secretariat. Federal Office for the Environment, Bern.
http://www.bafu.admin.ch/luft/11640/11641/11643/index.html?lang=de [26.02.2015]

FOEN 2015g: Zusammenstellung der Feedstocks basierend auf GEST-, EV- und bottom-up Industrie-Daten, BAFU, internal documentation (confidential, Excelfile), Federal Office for the Environment, Bern.

FOEN 2015h: CO_2-Emissionsfaktor Erdgas, Zeitreihe für das Treibhausgasinventar der Schweiz, internal documentation, Federal Office for the Environment, Bern.

FOEN 2015i: Estimation of carbon stock changes in Harvested Wood Products (HWP) from Swiss Forests – description of time series, modeling methodology for accounting under the Kyoto Protocol and results. Internal Report.
http://www.bafu.admin.ch/ghginv-CP2-ref

FOEN / SFOE / EAER (ed.) 2014: Wood Resource Policy. Strategy, Objectives and Wood Action Plan. Updated version 2014. Federal Office for the Environment FOEN, Federal Office of Energy SFOE, State Secretariat for Economic Affairs SECO.
http://www.bafu.admin.ch/publikationen/publikation/01002/index.html?lang=en [26.02.2015]

FOEN/SFOE/VBSA 2014: Einheitliche Heizwert- und Energiekennzahlenberechnung der Schweizer KVA nach europäischem Standardverfahren. Resultate 2013. Bern.
http://www.bafu.admin.ch/ghginv-CP2-ref

Gehrig-Fasel, J., Guisan, A., Zimmermann, N.E. (2007): Treeline shifts in the Swiss Alps: climate change or land abandonment? Journal of Vegetation Science 18: 571–582. DOI: 10.1111/j.1654-1103.2007.tb02571.x

Genossenschaft Ökostrom Schweiz 2014: Projekte zur Emissionsverminderung im Inland – Methanemissionsreduktion bei landwirtschaftlichen Biogasanlagen in der Schweiz (Bündel I) – Monitoringberichte zu Handen BAFU für die Jahre 2010, 2011 und 2012. Frauenfeld, Schweiz.

GES Biogas GmbH 2014: Projekte zur Emissionsverminderung im Inland – Methanemissionsreduktion bei landwirtschaftlichen Biogasanlagen in der Schweiz (Bündel II) – Monitoringberichte zu Handen BAFU für die Jahre 2011 und 2012. Zürich, Schweiz.

Ginzler, C. 2014: Crown cover and basal area in unproductive forest: special analysis of plots covered by aerial photographs and terrestrial NFI. Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf. Commissioned by the Federal Office for

the Environment FOEN, Bern.
http://www.bafu.admin.ch/ghginv-CP2-ref

Guidi, C., Vesterdal, L., Gianelle, D., Rodeghiero, M. (2014): Changes in soil organic carbon and nitrogen following forest expansion on grassland in the Southern Alps. Forest Ecology and Management 328: 103–116.

Giuliani, S. 2014: Energiebedarfswerte der Nutztiere für die Periode 1990-2012. Written communication from Silvano Giuliani (SBV, Swiss Farmers Union) to Daniel Bretscher (ART, Reckenholz), 21.10.2014.
http://www.bafu.admin.ch/ghginv-CP2-ref

Gkatzoflias, D., Kouridis, C., Ntziachristos, L. 2012: COPERT 4. Computer programme to calculate emissions from road transport. User manual (version 9.0). European Environment Agency.
http://emisia.com/copert [25.02.2015]

Grassi, G., Blujdea, V. 2011: Pools to be reported under KP-LULUCF. Harmonized guidance and decision tree on the application of "not a source" principle. Joint Research Centre, Ispra. Presentation at "JRC technical workshop on LULUCF issues under the Kyoto Procotol", 21 November 2011.

Gschwantner, T. 2006: Zuwachsänderungen nach den Daten der Österreichischen Waldinventur und ihre klimatischen Ursachen. [Growth changes according to the data of the Austrian National Forest Inventory and their climatic causes]. BFW-Berichte 133, Wien, Bundesamt für Wald.

Hackl, A., Mauschitz, G. 2003: Emissionen aus Anlagen der Österreichischen Zementindustrie IV. Jahresreihe 2000-2002. Weitra/Wien.
http://www.bafu.admin.ch/ghginv-ref

Hadorn, R., Wenk, C. 1996: Effect of different sources of dietary fibre on nutrient and energy utilization in broilers. 2. Energy and N-balance as well as whole body composition. Archiv für Geflügelkunde 60: 22-29.

Hagedorn, F., Martin, M., Rixen, C., Rusch, S., Bebi, P., Zürcher, A., Siegwolf, R.T.W., Wipf, W., Escape, C., Roy, J., Hättenschwiler, S. 2010: Short-term responses of ecosystem carbon fluxes to experimental soil warming at the Swiss alpine treeline. Biogeochemistry: 97: 7-19.
http://dx.doi.org/10.1007/s10533-009-9297-9

Hausberger S., Rexeis M., Zallinger M., Luz R. 2009: Emission Factors from the Model PHEM for the HBEFA Version 3.1., Graz; Report Nr. I-20/2009 Haus-Em 33/08/679, 2009.

Helmisaari, H.-S., Hallbäcken, L. 1998: Tree biomass below-ground. In: Andersson, F., Braekke, F.H., Hallbäcken, L. (eds.): Nutrition and growth of Norway spruce forests in a Nordic climatic and deposition gradient, TemaNord 1998: 566, Nordic Council of Ministers, Copenhagen: 80–90.
http://www.bafu.admin.ch/ghginv-ref

Hiller, R.V., Bretscher, B., DelSontro, T., Diem, T., Eugster, W., Henneberger, R., Hobi, S., Hodson, E., Imer, D., Kreuzer, M., Künzle, T., Merbold, L., Niklaus, P.A., Rihm, B., Schellenberger, A., Schroth, M.H., Schubert, C.J., Sigrist, H., Stieger, J., Buchmann, N., Brunner, D. 2014: Anthropogenic and natural methane fluxes in Switzerland synthesized

within a spatially explicit inventory. Biogeosciences 11: 1941-1959.
http://dx.doi.org/10.5194/bg-11-1941-2014

Hiller, R.V., Neininger, B., Brunner, D., Gerbig, Ch., Bretscher, D., Künzle, T. 2014a: Airborne CH_4 flux measurements for validation of emissions from an agriculturally dominated area in Switzerland. Journal of Geophysical Research. 119(8): 4874-4887.

Hindrichsen, I.K., Wettstein, H.-R., Machmüller, A., Bach Knudsen, K.E., Madsen, J., Kreuzer, M. 2006: Methane emission, nutrient degradation and nitrogen turnover in dairy cows and their slurry at different milk production scenarios with and without concentrate supplementation. Agricultural Ecosystems and Environment 113: 150–161.

Högber, P., Fan, H., Quist, M., Binkley, D., Tamm, C.O. 2006: Tree growth and soil acidification in response to 30 years of experimental nitrogen loading on boreal forest. Global Change Biology 12: 489-499.
http://dx.doi.org/10.1111/j.1365-2486.2006.01102.x

Hofer P., Altwegg, J. 2008: Holznutzungs-Potenziale im Schweizer Wald – auf Basis LFI3. Bundesamt für Umwelt, Bern. 38 p.
http://www.bafu.admin.ch/wald/01234/11652/index.html?lang=de [26.02.2015]

Hofer P., Altwegg, J., Schoop, A., Hässig, J., Ruegg, R. 2011: Holznutzungspotenziale im Schweizer Wald. Auswertung von Nutzungsszenarien und Waldwachstumsentwicklung. Bundesamt für Umwelt, Bern. Umwelt-Wisser Nr. 1116: 80 p.
http://www.bafu.admin.ch/ghginv-CP2-ref

Huber, B., Frehner M. 2012: Forschungsprojekt Grünerle. Bericht erstellt im Auftrag des Bundesamtes für Umwelt (BAFU), Bern. Abenis AG Chur und Forstingenieurbüro Monika Frehner, Sargans.

Huber, B., Frehner M. 2013: Die Verbreitung und Entwicklung der Grünerlenbestände in der Ostschweiz. Schweizerische Zeitschrift fur Forstwesen 164: 87-94.
http://www.szf-jfs.org/toc/swif/164/4 [04.04.2014]

Huber, T., Thürig, E. 2014: Special analysis of stocks of living biomass in non-productive forest (CC13) on terrestrial NFI plots. Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf. Commissioned by the Federal Office for the Environment FOEN, Bern.
http://www.bafu.admin.ch/ghginv-ref

Hürdler, J., Prasuhn, V., Spiess, E. 2015: Abschätzung diffuser Stickstoff- und Phosphoreinträge in die Oberflächengewässer der Schweiz. MODIFFUS 3.0. – Bericht im Auftrag des Bundesamtes für Umwelt BAFU, Agroscope, Zürich, ca. 115 S.

Hyvönen, R., Persson, T., Andersson, S., Olsson, B. Ågren, G.I., Linder, S. 2008: Impact of long-term nitrogen addition on carbon stocks in trees and soils in northern Europe. Biogeochemistry 89: 121-137.
http://dx.doi.org/10.1007/s10533-007-9121-3

IAI 2005: Aluminium for future Generations. Sustainability Update 2004. International Aluminium Institute, London.
http://www.bafu.admin.ch/ghginv-ref

IEA/EBRD 2010: Energy Efficiency Governance – Handbook, second edition, IEA/OECD Paris and EBRD, London.
http://www.iea.org/publications/freepublications/publication/gov_handbook-1.pdf [28.02.2015]

IEA 2005: Energy statistics manual, IEA/OECD Paris.
http://www.iea.org/publications/freepublications/publication/statistics_manual-1.pdf [25.01.2015]

IEA 2012: Energy statistics of OECD countries, 2012 edition, IEA/OECD Paris.
http://www.iea.org/stats/index.asp [06.11.2014]

IFEU/INFRAS 2009: Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland, Endbericht. IFEU und INFRAS im Auftrag des Umweltbundesamts Dessau/Deutschland, FKZ 360 16 023. Heidelberg/Zürich/Bern. 31. Oktober 2009.
http://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/3937.pdf [01.03.2015]

INFRAS 2004: Emission Factors for Passenger Cars and Light-Duty Vehicles. Handbook Emission Factors for Road Transport (HBEFA), Version 2.1. Swiss Agency for the Environment, Forests and Landscape, Bern, Umweltbundesamt, Berlin, Umweltbundesamt, Wien.
http://www.hbefa.net/e/index.html [02.12.2014]

INFRAS 2008: Treibstoffverbrauch und Schadstoffemissionen des Offroad-Sektors. Studie für die Jahre 1980–2020. [Offroad fuel consumption and pollutant emissions in Switzerland. Study for the period from 1980 to 2020]. Im Auftrag des Bundesamts für Umwelt. [On behalf of the Federal Office for the Environment]. Umwelt-Wissen Nr. 0828. Bern.
http://www.bafu.admin.ch/publikationen/publikation/01003/index.html?lang=de [28.02.2015] [in German with English, French and Italian abstract]
Offroad database [in English, French, German]:
http://www.bafu.admin.ch/luft/00596/06906/offroad-daten/index.html?lang=en [28.02.2015]

INFRAS 2010: The Handbook Emission Factors for Road Transport (HBEFA), version 3.1 (MS AccessXP runtime application and report). INFRAS in cooperation with further editors: FOEN/Switzerland; Umweltbundesamt Dessau/Germany; Umweltbundesamt Wien/Austria; Swedish Road Administration, ADEME/France; SFT/Norway. Bern. 30.01.2010.
http://www.hbefa.net/e/index.html [02.12.2014]

INFRAS 2011 (forthcoming): Handbuch Emissionsfaktoren des Strassenverkehrs 3.1. Dokumentation. Bern.
http://www.hbefa.net/e/index.html [28.01.2015]

INFRAS 2011a: Bunker fuels Bodensee/Genfersee, Datenverfügbarkeit und Berechnung der Bunker Fuels, September 2011.
http://www.bafu.admin.ch/ghginv-ref

INFRAS 2012: Verification of Swiss implied emission factors. INFRAS, Zürich.
http://www.bafu.admin.ch/ghginv-ref

INFRAS 2015: CO_2-Emissions from Carbonate, Assessment for FOEN. Internal documentation FOEN**.**
http://www.bafu.admin.ch/ghginv-CP2-ref

IPCC 1997a: Greenhouse Gas Inventory Reference Manual, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. Reporting Instructions (Volume 1). Intergovernmental Panel on Climate Change.
http://www.ipcc-nggip.iges.or.jp/public/gl/invs4.htm [24.02.2015]

IPCC 1997b: Greenhouse Gas Inventory Reference Manual, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. Workbook (Volume 2). Intergovernmental Panel on Climate Change.
http://www.ipcc-nggip.iges.or.jp/public/gl/invs5.htm [24.02.2015]

IPCC 1997c: Greenhouse Gas Inventory Reference Manual, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. Reference Manual (Volume 3). Intergovernmental Panel on Climate Change.
http://www.ipcc-nggip.iges.or.jp/public/gl/invs6.htm [9.12.2014]

IPCC 2000: Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPC C GPG). Intergovernmental Panel on Climate Change.
http://www.ipcc-nggip.iges.or.jp/public/gp/english/ [06.11.2014]

IPCC 2003: Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC GPG LULUCF).
http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.htm [27.01.2014]

IPCC 2006: 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change.
http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm [28.11.2014]

IPCC 2014: 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (KP Supplement). Intergovernmental Panel on Climate Change. Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M. and Troxler, T.G. (eds). Published: IPCC, Switzerland
http://www.ipcc-nggip.iges.or.jp/public/kpsg/index.html [06.03.2015]

IPCC 2014a: 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands, Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M. and Troxler, T.G. (eds). Published: IPCC, Switzerland.
http://www.ipcc-nggip.iges.or.jp/public/wetlands/index.html [06.03.2015]

ISPRA 2014: Italian Greenhouse Gas Inventory 1990-2012. Inventory Report and CRF-tables. Submission to the UNFCCC Secretariat 2014. Instituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA). Rome, Italy.

Jandl, R., Lindner, M., Vesterdal, L., Bauwens, B., Baritz, R., Hagedorn, F., Johnson, D. W., Minkkinen, K., Byrne, K. A. 2007: How strongly can forest management influence soil carbon sequestration? Geoderma 137: 253-268.
http://dx.doi.org/10.1016/j.geoderma.2006.09.003

Jarvis, P.G., Linder, S. 2000: Constraints to growth of boreal forests. Nature 405: 904-905.
http://dx.doi.org/10.1038/35016154

Karhu, K., Wall, A., Vanhala, P., Liski, J., Esala, M., Regina, K. 2011: Effects of afforestation and deforstation on boreal soil carbon stocks - Comparison of measured C stocks with Yass07 model results. Geoderma 164: 33-45.
http://dx.doi.org/10.1016/j.geoderma.2011.05.008

Karl, T., Guenther, A., Lindinger, C., Jordan, A., Fall, R., Lindinger, W. 2001: Eddy covariance measurements of oxygenated volatile organic compound fluxes from crop harvesting using a redesigned proton-transfer-reaction mass spectrometer. Journal of Geophysical Research 106 D20: 24157-24167. http://dx.doi.org/10.1029/2000JD000112

Kaufmann, E. 2001: Estimation of Standing Timber, Growth and Cut. In: Brassel, P.; Lischke, H. (eds). Swiss National Forest Inventory: Methods and Models of the Second Assessment. Birmensdorf, Swiss Federal Research Institute WSL. 162–196. http://www.lfi.ch/publikationen/publ/methods/methods.pdf [28.02.2013]

Kaufmann, E. 2001a: Prognosis and Management Scenarios. In: Brassel, P.; Lischke, H. (eds) Swiss National Forest Inventory: Methods and Models of the Second Assessment. Birmensdorf, Swiss Federal Research Institute WSL. 197-206.http://www.lfi.ch/publikationen/publ/methods/methods.pdf [28.02.2013]

Kaufmann, E. 2005: Personal communication from Edgar Kaufmann (WSL, Zürich) to Esther Thürig (FOEN, Bern), 12.12.2005. http://www.bafu.admin.ch/ghginv-ref

Kaufmann, E. 2011: Nachhaltiges Holzproduktionspotenzial im Schweizer Wald. Schweizerische Zeitschrift für Forstwesen 162 (9): 300–311. doi:10.3188/szf.2011.0300.

Kaufmann, U. 2013: Energieverbrauch stationäre Motoren und Gasturbinen ab 1990. Excel data file for internal use on behalf of the Federal Office for the Environment, Bern. Eicher + Pauli, Liestal.

de Keizer et al. 2007: See above under character D (de Keizer)

Keller, J., Andreani-Aksoyoglu, S., Joss, U. 1995: Inventory of natural emissions in Switzerland. In: Power, H., Moussiopoulos, N., Brebbia C.A. (eds.): Air Pollution III, Volume 2, Air Pollution Engineering and Management: 339-346. Computational Mechanics Publications. http://www.bafu.admin.ch/ghginv-ref

Keller, A., Rossier, N., Desaules, A. 2005: Schwermetallbilanzen von Landwirtschaftsparzellen der Nationalen Bodenbeobachtung. NABO – Nationales Bodenbeobachtungsnetz der Schweiz. [Heavy-metal balances of agricultural soil monitoring sites. NABO – Swiss Soil Monitoring Network]. Schriftenreihe der FAL 54, Zürich-Reckenholz. http://www.bafu.admin.ch/ghginv-ref

Keller, A., Desaules, A., Schwab, P., Weisskopf, P., Scheid, S., Oberholzer, H.-R. 2006: Monitoring soil quality in the long term: examples from the Swiss Soil Monitoring Network. Mitteilungen der Österreichischen Bodenkundlichen Gesellschaft, Heft 73: 5-12. http://www.bafu.admin.ch/ghginv-ref

Keller, A. 2013: Details on NABO soil data uncertainties. Written communication from Armin Keller (Agroscope) to Daniel Bretscher (ART), 28.01.2013. http://www.bafu.admin.ch/ghginv-ref

Keller/INFRAS 2013: Data were provided by M. Keller to FOEN. E-Mail 07.05.2013 from M.Keller (INFRAS) to B. Müller (FOEN).

Knighton, W.B., Herndon, S.C., Miake-Lye, R.C. 2009: Aircraft Engine Speciated Organic Gases: Speciation of Unburned Organic Gases in Aircraft. US EPA-420-R-09-902. May 2009 http://www.epa.gov/nonroad/aviation/420r09902.pdf [28.02.2015]

Koehlerei, 2014: Geschichte der Holzköhlerei in Romoos. http://www.koehlerei.ch/ [09.12.2014]

Koehli L. 2014: Landwirtschaftliche Biogasanlagen. Written communication from Lorenz Koehli (Oekostrom Schweiz) to Daniel Bretscher (Agroscope), 27.08.2014.

Köck, K., Leifeld, J., Fuhrer, J. 2013: A model-based inventory of sinks and sources of CO_2 in agricultural soils in Switzerland: development of a concept. Agroscope, Zürich. http://www.bafu.admin.ch/ghginv-ref

König, G., Brunda, M., Puxbaum, H., Hewitt, C.N., Duckham, S.C., Rudolph, J. 1995: Relative contribution of oxygenated hydrocarbons to the total biogenic VOC emissions of selected mid-European agricultural and natural plant species. Atmospheric Environment 29: 861–874.
http://dx.doi.org/10.1016/1352-2310(95)00026-U

Kreuzer 2012: Wissenschaftlicher Schlussbericht zuhanden des BAFU und des BLW für das Projekt: Technische Massnahmen und deren Potenzial zur Reduktion der THG CH_4 und N_2O aus der Schweizer Tierhaltung. ETH 10.2. 2012.
http://www.bafu.admin.ch/ghginv-ref

Külling, D. R., Dohme, F., Menzi, H., Sutter, F., Lischer, P., Kreuzer, M. 2002: Methane emissions of differently fed dairy cows and corresponding methane and nitrogen emissions from their manure during storage. Environmental Monitoring and Assessment 79 (2): 129-150.

Külling D. R., Stadelmann F. X., Candinas T. 2002a: Nährstoffe und Schwermetalle im Klärschlamm 1975–1999, Agrarforschung 9(5): 200-205.

Külling, D. R., Menzi, H., Sutter, F., Lischer, P., Kreuzer, M. 2003: Ammonia, nitrous oxide and methane emissions from differently stored dairy manure derived from grass- and hay-based rations. Nutrient Cycling in Agroecosystems 65 (1): 13-22.

Kupper, T., Bonjour, C., Achermann, B., Zaucker, F., Rihm, B., Menzi, H. 2013: Ammoniakemissionen in der Schweiz 1990-2010 und Prognose bis 2020. Hochschule für Agrar-, Forst- und Lebensmittelwissenschaften, Zollikofen. URL: http://www.agrammon.ch/dokumente-zum-download/ [26.02.2015]

Lamlom, S.H., Savidge, R.A. 2003: A reassessment of carbon content in wood: variation within and between 41 North American species. Biomass and Bioenergy 25: 381-388. http://dx.doi.org/10.1016/S0961-9534(03)00033-3

Leifeld, J., Bassin, S., Fuhrer, J. 2003: Carbon stocks and carbon sequestration potentials in agricultural soils in Switzerland. Schriftenreihe der FAL 44. Zürich-Reckenholz. http://www.bafu.admin.ch/ghginv-ref

Leifeld, J., Bassin, S., Fuhrer, J. 2005: Carbon stocks in Swiss agricultural soils predicted by land-use, soil characteristics, and altitude. Agriculture, Ecosystems & Environment 105 (1/2): 255-266.
http://dx.doi.org/10.1016/j.agee.2004.03.006

Leifeld, J., Fuhrer, J. 2005: Greenhouse gas emissions from Swiss agriculture since 1990: Implications for environmental policies to mitigate global warming. Environmental Science & Policy 8: 410-417.
http://dx.doi.org/10.1016/j.envsci.2005.04.001

Leifeld, J., Zimmermann, M., Fuhrer, J. 2007: Characterization of soil carbon stocks and site-specific sequestration potentials of agricultural soils. Extended Summary. Final Report, Contract Number: 810.03.0716 / 2003.C.04. Agroscope Reckenholz-Tänikon Research Station ART.
http://www.bafu.admin.ch/ghginv-ref

Leifeld, J., Reiser, R., Oberholzer, H.R. 2009: Consequences of conventional versus organic farming on soil carbon: Results from a 27-year field experiment. Agronomy Journal 101: 1204-1218.
http://dx.doi.org/10.2134/agronj2009.0002

Leupro 2012: Entwicklung und Prognose der Emissionsfaktoren Feuerungen für den Zeitraum 1990 – 2035.
http://www.bafu.admin.ch/ghginv-ref

LHA 2004: Letter of „Lufthygieneamt beider Basel“ to FOEN, Basel, 04.05.2004.

Mangino, J., Bartram, D., Brazy, A. 2001: Development of a methane factor to estimate emissions from animal waste lagoons. U.S.EPA's 17th Annual Emission Inventory Conference, Atlanta GA; U.S. EPA.

Martínez-Fernández, G., Abecia, L., Ramos-Morales, E., Martin-García, A.I., Molina-Alcaide, E., Yáñez-Ruiz, D.R. 2014: Effects of propyl propane thiosulfinate on nutrient utilization, ruminal fermentation, microbial population and methane emissions in goats. Animal Feed Science and Technology 191(0): 16-25.

Mathys, L., Thürig E. 2010: Baumbiomasse in der Landschaft. [Living biomass of trees in Non-Forest Land]. Final report, Sigmaplan and WSL on behalf of the Federal Office for the Environment, Bern.
http://www.bafu.admin.ch/ghginv-ref

Meining, S., V.Wilpert, K., Schäffer, J., Schröter, H. 2008: Waldzustandsbericht 2008 der Forstlichen Versuchs- und Forschungsanstalt Baden- Württemberg. Freiburg .

Menzi, H. 2014: Stickstoffausscheidung Kaninchen. Written communication from Harald Menzi (Agroscope INT) to Daniel Bretscher (Agroscope INH), 05.12.2014.

MeteoSwiss (Federal Office of Meteorology and Climatology), 2012a: Documentation of MeteoSwiss Grid-Data Products Mean Monthly and Yearly Mean Temperature (1961-1990): TnormM6190 and TnormY6190. Federal Office of Meteorology and Climatology MeteoSwiss, Zurich.

MeteoSwiss (Federal Office of Meteorology and Climatology), 2012b: Documentation of MeteoSwiss Grid-Data Products Monthly and Yearly Precipitation: RhiresM and RhiresY. Federal Office of Meteorology and Climatology MeteoSwiss, Zurich.

MeteoSwiss (Federal Office of Meteorology and Climatology) 2014: Normwerte 1981-2010: Lufttemperatur 2m. Federal Office of Meteorology and Climatology MeteoSwiss, Zurich.

Meteotest 2015: Treibhausgasinventar Sektor LULUCF, Tabellen zur Berechnung der Treibhausgasemissionen im Sektor LULUCF in der Schweiz inklusive Begleitdokumentation. Internes Dokument. [GHG inventory, sector LULUCF. Spreadsheets to calculate the GHG emissions of the LULUCF sector in Switzerland inclusive accompanying documents. Internal document]. Meteotest, Bern.

Meyer, H., Coenen, M., 2002: Pferdefütterung. Parey Buchverlag Berlin, 4. Auflage; ISBN 3-8263-3398-5.

Minonzio, G., Grub, A., Fuhrer, J. 1998: Methanemissionen der schweizerischen Landwirtschaft. Schriftenreihe Umwelt Nr. 298. FOEN / BUWAL, Bern.

MISTA 2014: Milchstatistik der Schweiz 2013. Schweizerischer Bauernverband (SBV), TSM Treuhand GmbH, Schweizer Milchproduzenten (SMP).

Moeri, A.C. 2007: Kohlenstoffvorräte in Schweizer Waldböden mit besonderer Berücksichtigung der organischen Auflage. Diplomarbeit bei der Eidgenössischen Forschungsanstalt für Wald, Schnee und Landschaft (WSL). Geographisches Institut der Universität Zürich.
http://www.bafu.admin.ch/ghginv-ref

Mohn, J. 2011: Bestimmung des Anteils biogener und fossiler CO_2 Emissionen aus Schweizer KVAs. Eidg. Materialprüfungsanstalt und Forschungsanstalt. Schlussbericht. Im Auftrag des Bundesants für Umwelt.
http://www.bafu.admin.ch/ghginv-ref

Mohn, J. 2013: Bestimmung der N_2O und CH_4 Emissionen aus Schweizer KVAs. Eidg. Materialprüfungs- und Forschungsanstalt. Schlussbericht. Im Auftrag des Bundesamts für Umwelt.
http://www.bafu.admin.ch/ghginv-CP2-ref

Moller, H.B., Sommer, S.G., Ahring, B.K. 2004: Biological degradation and greenhouse gas emissions during pre-storage of liquid animal manure. Journal of Environmental Quality 33 (1): 27-36.

Monni, S., Peltoniemi, M., Palosuo, T., Lehtonen, A., Mäkipää, R., Savolainen, I. 2007: Uncertainty of forest carbon stock changes – implications to the total uncertainty of GHG inventory of Finland. Climatic Change 81: 391-413.
http://dx.doi.org/10.1007/s10584-006-9140-4

Nave, L.E., Vance, E.D., Swanston, C. W., Curtis, P.S. 2010: Harvest impacts on soil carbon storage in temperate forests. Forest Ecology and Management 259: 857-866.
http://dx.doi.org/10.1016/j.foreco.2009.12.009

Nousiainen, J., Rinne, M., Huhtanen, P. 2009: A meta-analysis of feed digestion in dairy cows. 1. The effects of forage and concentrate factors on total diet digestibility. Journal of dairy science 92(10): 5019-5030.

Nowak, D., Crane, D. 2002: Carbon storage and sequestration by urban trees in the USA. Environmental Pollution 116: 381–389.
http://dx.doi.org/10.1016/S0269-7491(01)00214-7

Nussbaum, M., Papritz, A., Baltensweiler, A., Walthert, L. 2012: Organic Carbon Stocks of Swiss Forest Soils. Final Report. Institute of Terrestrial Ecosystems, ETH Zürich and

Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf. http://dx.doi.org/10.3929/ethz-a-007555133

Nussbaum, M., Papritz, A., Baltensweiler, A., Walthert, L. 2014: Estimating soil organic carbon stocks of Swiss forest soils by robust external-drift kriging. Geoscientific Model Development 7: 1197-1210.
http://dx.doi.org/10.5194/gmd-7-1197-2014

Nussbaumer, T., Hälg, L. 2015: Emissionsfaktoren von Holzfeuerungen – Aktualisierung und Ergänzung 2014. Verenum im Auftrag des Bundesamtes für Umwelt (BAFU) 2015 inkl. Excelfile. (draft)

OcCC 2008: Das Klima ändert – was nun? Der neue UN-Klimabericht (IPCC 2007) und die wichtigsten Ergebnisse aus Sicht der Schweiz. The Advisory Body on Climate Change, Bern. http://proclimweb.scnat.ch/Products/OcCC-IPCC/OcCC-IPCC-lowres.pdf [24.02.2015]

OE 2015: Liechtenstein's Greenhouse Gas Inventory 1990-2013, National Inventory Report under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol, Submission 2015 to the United Nations Framework Convention on Climate Change. Office of Environmental Protection (OEP). Principality of Liechtenstein. Vaduz, forthcoming.

OECD 2013: Agricultural policy monitoring and evaluation 2013: OECD countries and emerging economies. Organisation for Economic Co-operation and Development (OECD); Paris, France.

Oekostrom 2014: Factsheet Digestate 17.07.2014 handed out to FOEN for internal use only (confidential).

Park, K.H., Thompson, A.G., Marinier, M., Clark, K., Wagner-Riddle, C. 2006: Greenhouse gas emissions from stored liquid swine manure in a cold climate. Atmospheric Environment 40 (4): 618-627.

Paul, C., Weber, M., Mosandl, R. 2009: Kohlenstoffbindung junger Aufforstungsflächen. Literaturstudie. Karl Gayer Institut und Lehrstuhl für Waldbau der Technischen Universität München, Freising, 70 p. https://mediatum.ub.tum.de/doc/1219390/1219390.pdf

Perruchoud, D., Kienast, F., Kaufmann, E., Bräker, O.U 1999: 20th Century Carbon Budget of Forest Soils in the Alps. Ecosystems 2: 320-337.
http://dx.doi.org/10.1007/s100219900083

Peter, S., Hartmann, M., Hediger, W. 2006: Entwicklung der landwirtschaftlichen Emissionen umweltrelevanter Stickstoffverbindungen. Schlussbericht, Dezember 2006. Schriftenreihe Info Agrar Wirtschaft 2006/1. ETH Zürich; Institute for Environmental Decisions IED.
http://www.bafu.admin.ch/ghginv-ref

Poncet, P.-A., Guillet, A., Jallon, L., Lüth, A., Martin, R., Montavon, S., Sunier, E., Trolliet, Ch. F., Wohlfender, K. 2007: Wirtschafts-, gesellschafts- und umweltpolitische Bedeutung des Pferdes in der Schweiz. Bericht der Arbeitsgruppe Pferdebranche. Avenche, Schweiz.

Poncet, P.-A., Boessinger, M., Guillet, A., Klopfenstein, S., König-Bürgi, D., Lüth, A., Martin, R., Montavon, S., Obexer-Ruff, G., Rieder, S., Rubli, S., Rüegg, P., Trolliet, Ch. F. 2009: Wirtschafts-, gesellschafts- und umweltpolitische Bedeutung des Pferdes in der

Schweiz – Was gibt es Neues seit 2007? Bericht der Arbeitsgruppe Pferdebranche. Avenche, Schweiz.

Prognos 2012a: Die Energieperspektiven für die Schweiz bis 2050 – Energienachfrage und Elektrizitätsangebot in der Schweiz 2000-2050. Prognos AG im Auftrag des Bundesamtes für Energie, Basel.
http://www.bfe.admin.ch/themen/00526/00527/index.html?lang=de&dossier_id=05024 [20.01.2015]

Prognos 2013: CO_2-Emissionen 1990-2012 von Industrie- und Dienstleistungen, Endbericht / Kurzdokumentation zuhanden Bundesamt für Umwelt, Bern. Prognos, Basel.

Quantis 2014: Methanemissionen der Schweizer Gaswirtschaft. Zeitreihe 1990 bis 2012. Schlussbericht. Quantis im Auftrag des Schweizerischen Vereins des Gas- und Wasserfaches SVGW und des Bundesamts für Umwelt BAFU.
http://www.bafu.admin.ch/ghginv-ref

Ramin, M., Huhtanen, P. 2012: Development of non-linear models for predicting enteric methane production. Acta Agriculturae Scandinavica, Section A — Animal Science 62(4): 254-258.

RAP 1999: Fütterungsempfehlungen und Nährwerttabellen für Wiederkäuer [Apports alimentaires recommandés et tables de la valeur nutritive des aliments pour les ruminants]. Landwirtschaftliche Lehrmittelzentrale, Zollikofen. Vierte Auflage.

Richard, L. 1995: Ecologie des mégaphorbiaies subalpines à aune vert de la Vanoise et des régions environnantes (seconde partie) – Phytoécologie. Trav Sci Parc Nat Vanoise 19: 131-160.

Rigling, A., Schaffer, H.P. (Eds.) 2015: Forest Report 2015. Condition and Use of Swiss Forests. Federal Office for the Environment (FOEN), Bern, Swiss Federal Institute (WSL), Birmensdorf. 143 pages.

Rühr, N., Eugster, W. 2009: Soil respiration fluxes and carbon sequestration of two mountain forests in Switzerland. Report on behalf of the Federal Office for the Environment, Bern.
http://www.bafu.admin.ch/ghginv-ref

Ruffner, H.P. 2005: Written communication from Hans Peter Ruffner (Forschungsanstalt Wädenswil) to Jens Leifeld (ART, Reckenholz), 19.12.2005.
http://www.bafu.admin.ch/ghginv-ref

Rusch, S., Hagedorn, F., Zimmermann, S., Lüscher, P. 2009: Bodenkohlenstoff nach Windwurf – eine CO_2-Quelle? [Soil carbon after wind throw – a source of CO_2?]. Report on behalf of the Federal Office for the Environment. [German]
http://www.bafu.admin.ch/ghginv-ref

Ryan, M. G., Binkley, D., Fownes, J. H., Giardina, C. P., Senock, R. S. 2004: An experimental test of the causes of forest growth decline with stand age. Ecological Monographs 74: 393-414.

Rytec 2010: Review of the waste sector of the national greenhouse gas inventory of Switzerland. Final report. Rytec AG, Münsingen. http://www.bafu.admin.ch/ghginv-ref

Rytec 2014: Fossiler Kohlenstoffanteil im verbrannten Abfall 1992 – 2012. Errechnung einer Zeitreihe aus der Verknüpfung der Rauchgasmessung 2010/11 und der erhobenen

Kehrichtzusammensetzung 1992, 2002, 2012. Rytec AG, Münsingen.
http://www.bafu.admin.ch/ghginv-CP2-ref

SAEFL 1992: Abfallkonzept für die Schweiz, Schriftenreihe Umwelt Nr. 173. Swiss Agency for the Environment, Forests and Landscape, Bern.

SAEFL 1993: NABO - Nationales Bodenbeobachtungsnetz. Messresultate 1985-1991. [NABO - Réseau d'observation des sols: période d'observation 1985-1991]. Schriftenreihe Umwelt Nr. 200. [Cahier de l'environnement No 200]. Swiss Agency for the Environment, Forests and Landscape, Bern.
http://www.bafu.admin.ch/publikationen/publikation/00321/index.html?lang=de [German] [26.02.2015]

SAEFL 1995: Emissionen des Strassenverkehrs 1950-2010. [Emissions polluantes du trafic routier de 1950 à 2010]. Schriftenreihe Umwelt Nr. 255. [Cahier de l'environnement No 255]. Swiss Agency for the Environment, Forests and Landscape, Bern. [available in German and French].

SAEFL 1996: Schadstoffemissionen und Treibstoffverbrauch des Offroad Sektors, Umwelt-Materialien Nr. 49. Elektrowatt Ingenieurunternehmung AG, Zürich; Technik Thermische Maschinen, Niederrohrdorf; Swiss Agency for the Environment, Forests and Landscape, Bern.

SAEFL 1996a: Luftschadstoff-Emissionen aus natürlichen Quellen der Schweiz. [Emissions polluantes dues aux sources naturelles en Suisse]. Schriftenreihe Umwelt Nr. 257. [Cahier de l'environnement No 257]. Swiss Agency for the Environment, Forests and Landscape, Bern.
http://www.bafu.admin.ch/ghginv-ref

SAEFL 2000: Handbuch Emissionsfaktoren für stationäre Quellen. Ausgabe 2000, Reihe Vollzug Umwelt. Swiss Agency for the Environment, Forests and Landscape, Bern.

SAEFL 2000a: Nationales Boden-Beobachtungsnetz - Veränderungen von Schadstoffgehalten nach 5 und 10 Jahren. [Réseau national d'observation des sols - Variations des teneurs en polluants après 5 et 10 ans de suivi]. Schriftenreihe Umwelt Nr. 320. [Cahier de l'environnement No 320]. Swiss Agency for the Environment, Forests and Landscape, Bern.
http://www.bafu.admin.ch/publikationen/publikation/00470/index.html?lang=de [German] [26.02.2015]

SAEFL 2004a: Handbook Emission Factors for Road Transport. Swiss Agency for the Environment, Forests and Landscape / INFRAS, CD ROM, Bern.
http://www.bafu.admin.ch/luft/00596/00597/00605/index.html?lang=en [28.02.2014]

SAEFL 2005h: Personal communication from R. Quartier (SAEFL, Bern) to J. Füssler (Ernst Basler + Partner, Zollikon), 23 February 2005.
http://www.bafu.admin.ch/ghginv-ref

SBV 2004: Statistiques et évaluations concernant l'agriculture et l'alimentation, 2003. [Statistische Erhebungen und Schätzungen über Landwirtschaft und Ernährung 2003]. Swiss Farmers Union, Brugg. [available in German and French]

SBV 2007: Statistiques et évaluations concernant l'agriculture et l'alimentation, 2006. [Statistische Erhebungen und Schätzungen über Landwirtschaft und Ernährung, 2006]. Swiss Farmers Union, Brugg. [available in German and French]

SBV 2007a: Données mensuelles sur l'agriculture. 67.8. August 2007. [Landwirtschaftliche Monatszahlen 67.8. August 2007]. Swiss Farmers Union, Brugg. [available in German and French]
http://www.bafu.admin.ch/ghginv-ref

SBV 2014: Statistiques et évaluations concernant l'agriculture et l'alimentation, 2013. [Statistische Erhebungen und Schätzungen über Landwirtschaft und Ernährung, 2013]. Swiss Farmers Union, Brugg. [available in German and French]
http://www.sbv-usp.ch/de/statistik/ [28.09.2014]

Schenk 1997: Schenk, M. .K., Appel, S. and Daum, D. 1997. N2O EMISSIONS DURING COMPOSTING OF ORGANIC WASTE (REFEREED). Acta Hort. (ISHS) 450:253-262.
http://www.actahort.org/books/450/450_30.htm [02.03.2015]

Schlegel, P., Menzi, H. 2013: Schweizer Kaninchenproduktion und deren Stickstoff-, Phosphor- und Kaliumausscheidung. Agrarforschung Schweiz 4(2): 60–67.

Schmid, M., Neftel, A., Fuhrer, J. 2000: Lachgasemissionen aus der Schweizer Landwirtschaft. [Emissions de protoxyde d'azote de l'agriculture Suisse]. Schriftenreihe der FAL 33. Zürich-Reckenholz.
http://www.bafu.admin.ch/ghginv-ref

Schneider, M. 2010: Personal communication from Manuel Schneider (ART, Reckenholz) to Daniel Bretscher (ART, Reckenholz), 21.09.2010.
http://www.bafu.admin.ch/ghginv-ref

Schwager, S. 2005: Personal communication from Stefan Schwager (FOEN, Bern) to Andreas Liechti (FOEN, Bern), 23.12.2005.
http://www.bafu.admin.ch/ghginv-ref [26.02.2015]

Schwarz, W. 2001: Emissionen des Kältemittels R-134a aus mobilen Klimaanlagen. Jährliche Emissionsraten von bis zu sieben Jahre alten Pkw-Klimaanlagen. [Emission of Refrigerant R-134a from Mobile Air-Conditioning Systems Annual Rate of Emission from Passenger-Car Air-Conditioning Systems up to Seven Years Old]. Gutachten durch die Oeko-Recherche GmbH für das Umweltbundesamt (FKZ 360 09 006), Frankfurt.

Schwarz, W., Wartmann, S. 2005: Emissionen und Emissionsprognosen von H-FKW, FKW und SF_6 in Deutschland – Aktueller Stand und Entwicklung eines Systems zur jährlichen Ermittlung. Gutachten durch die Oeko-Recherche GmbH für das Umweltbundesamt (FKZ 202 41 356), Frankfurt.

Schweizerischer Bundesrat 2008: Verordnung des EVD über Ethoprogramme (Ethoprogrammverordnung), 25. Juni 2008 (Stand am 1. Oktober 2008). Der Schweiz. Bundesrat, Bern, Schweiz.

SECO 2015: GDP and expenditure-side components (yearly and quarterly data). State Secretariat for Economic Affairs SECO.
http://www.seco.admin.ch/themen/00374/00456/04878/index.html?lang=en [09.02.2015]

SFCA 2014: Mineralölsteuer: Versteuerte Mengen 2013.
http://www.ezv.admin.ch/zollinfo_firmen/04020/04256/04263/04521/04523/index.html?lang=de [23.01.2015]

SFCA 2014a: Eidgenössische Zollverwaltung. Responsible for control of the import and export of certain goods, protection of agriculture; protection of trade marks, indications of geographical origin, design and copy rights; national economic supply. https://www.swiss-impex.admin.ch/

SFCA 2014b: Bunkers of diesel oil 1990-2013. Written communication Wolfgang Kobler (SCA) to Anouk Bass (FOEN).

SFOE 1999: „Ökologischer, energetischer und ökonomischer Vergleich von Vergärung, Kompostierung und Verbrennung fester biogener Abfallstoffe", Edelmann W., Schleiss K.

SFOE 2010: Tanktourismus. Swiss Federal Office of Energy, Bern. In German, with Summary in French. http://www.news.admin.ch/NSBSubscriber/message/attachments/19578.pdf [3.04.2015]

SFOE 2012: Schweizerische Gesamtenergiestatistik 2011. Statistique globale suisse de l'énergie 2011. Swiss Federal Office of Energy, Bern. In German and French. http://www.bfe.admin.ch/php/modules/publikationen/stream.php?extlang=de&name=de_872595201.pdf [28.01.2015]

SFOE 2014: Schweizerische Gesamtenergiestatistik 2013. Statistique globale suisse de l'énergie 2013. Swiss Federal Office of Energy, Bern. In German and French. http://www.bfe.admin.ch/php/modules/publikationen/stream.php?extlang=de&name=de_208577679.pdf&endung=Schweizerische%20Gesamtenergiestatistik%202013 [06.11.2014]

SFOE 2014a: Swiss renewable energy statistics. Ausgabe 2013. Swiss Federal Office of Energy, Bern. http://www.bfe.admin.ch/themen/00526/00541/00543/?dossier_id=00772&lang=de [28.11.2014]

SFOE 2014b: Schweizerische Holzenergiestatistik. Erhebung für das Jahr 2013. Swiss Federal Office of Energy, Bern. http://www.bfe.admin.ch/php/modules/publikationen/stream.php?extlang=de&name=de_547780234.pdf&endung=Schweizerische%20Holzenergiestatistik%202013 [German, with French summary] [02.12.2014]

SFOE 2014c: Thermische Stromproduction inklusive Wärmekraftkopplung (WKK) in der Schweiz. Ausgabe 2013. Swiss Federal Office of Energy, Bern. http://www.bfe.admin.ch/themen/00526/00541/00543/index.html?lang=de&dossier_id=00774 [German, with French summary] [23.02.2014]

SFOE 2014d: Energieverbrauch in der Industrie und im Dienstleistungssektor. Resultate 2013. Swiss Federal Office of Energy, Bern. http://www.bfe.admin.ch/php/modules/publikationen/stream.php?extlang=de&name=de_736430449.pdf&endung=Energieverbrauch%20in%20der%20Industrie%20und%20im%20Dienstleistungssektor [German, with French summary] [16.01.2015]

SFOE/FOEN 2014: Messung von Heizwerten und CO_2-Emissionsfaktoren von Erdölprodukten 2013. Statistische Analyse der Messresultate, Bern.

SFSO 1997: Digital terrain model („Geländedaten", 100m-Raster). Swiss Federal Statistical Office, GEOSTAT, Neuchâtel. http://www.bfs.admin.ch/bfs/portal/fr/index/dienstleistungen/geostat/datenbeschreibung/gelaendedaten.html [13.03.2013]

SFSO 2000a: Digital soil map 1:200'000 („Bodeneignungskarte“, BEK). Swiss Federal Statistical Office, GEOSTAT, Neuchâtel http://www.bfs.admin.ch/bfs/portal/fr/index/dienstleistungen/geostat/datenbeschreibung/digitale_bodeneignungskarte.html [2.4.2015]

SFSO 2002: Einblicke in die schweizerische Landwirtschaft. [Insights into Swiss Agriculture]. Swiss Federal Statistical Office, Neuchâtel. [available in German and French]

SFSO 2005: Swiss Land Use Statistics (Arealstatistik Schweiz). Supply of hectare-based data of the first survey (Arealstatistik 1979/85, ASCH1) and second survey (Arealstatistik 1992/97, ASCH2). Swiss Federal Statistical Office, Neuchâtel. http://www.bfs.admin.ch/bfs/portal/fr/index/infothek/erhebungen__quellen/blank/blank/arealstatistik/01.html [13.03.2013]

SFSO 2006a: Arealstatistik 2004/09 - Kategorienkatalog. Bodenbedeckung, Bodennutzung. Sektion Geoinformatik, Swiss Federal Statistical Office, Neuchâtel. http://www.bafu.admin.ch/ghginv-ref

SFSO 2009a: Volkswirtschaftliche Gesamtrechnung der Schweiz im Jahr 2008 (National Accounting 2008) Bruttoinlandprodukt (BIP), Swiss Federal Statistical Office, Neuchatel, November 2009. http://www.bfs.admin.ch/bfs/portal/de/index/themen/04/22/publ.html?publicationID=3777 [09.02.2015]

SFSO 2009c: Actualités OFS: Prestations du transport privé de personnes par la route, Séries chronologiques actualisées jusqu’en 2008, Neuchâtel 2010.

SFSO 2010c: Fahrzeugbewegungen und Fahrleistungen im Güterverkehr, bis 2008, Neuchâtel 2010.

SFSO 2013: Supply of provisional data of the AREA Land Use Statistics. Written communication from Felix Weibel and Jürg Burkhalter (SFSO, Neuchâtel) to Lukas Mathys (Sigmaplan, Bern), 16.07.2013. http://www.bafu.admin.ch/ghginv-ref

SFSO 2014a: Die Bevölkerung der Schweiz 2013. Swiss Federal Office. Neuchâtel. http://www.bfs.admin.ch/bfs/portal/de/index/themen/01/02/blank/dos/mittlere/01.html [09.02.2015]

SFSO 2014d: STAT-TAB: Die interaktive Statistikdatenbank; Datenwürfel für Thema 07.2 – Landwirtschaft. Swiss Federal Statistical Office, Neuchâtel.

SFSO 2014e: Background data of the Gross Nutrient Balance of the Swiss Federal Statistical Office. Swiss Federal Statistical Office, Neuchâtel.

SFSO 2015: Switzerland’s road vehicle stock. Swiss Federal Statistical Office http://www.bfs.admin.ch/bfs/portal/de/index/themen/11/03/blank/02.html [20.01.2015]

SGWA 2014: Eigenschaften des in der Schweiz verteilten Erdgases. G10001d, Ausgabe Mai 2014. Swiss Gas and Water Industry Association. http://www.svgw.ch/fileadmin/resources/svgw/web/Shop-Boutique/download/07_G-Merkblaetter/SVGW_Shop_G10001_d_2014.pdf [31.3.2015]

SHL 2010: Bestimmung Tiere der Rindviehkategorien ab 2009 für die Berechnung des Ammoniakinventars. Schweizerische Hochschule für Landwirtschaft SHL, Zollikofen.

SIA 1988: Norm Nr. 318, Garten- und Landschaftsbau (Practice Guidance No. 318 on Gardening and Landscaping Operations). Swiss Society of Engineers and Architects (SIA). http://www.webnorm.ch/481573fd-6a93-4890-9aa6-96b16753f4c2/D/DownloadAnhang [30.03.2015]

Sigmaplan 2010a: Deforestation under Kyoto Protocol. Documentation of implementation. Internal documentation by Mathys, L., Sigmaplan, Bern on behalf of the Federal Office for the Environment, Bern.
http://www.bafu.admin.ch/ghginv-ref

Sigmaplan 2012a: LULUCF and KP-LULUCF. Comparison of deforstation data. Final Report. Internal document. Sigmaplan, Bern.
http://www.bafu.admin.ch/ghginv-ref

Sigmaplan 2014: Treibhausgasinventar Sektor LULUCF, Tabellen zur Berechnung der Aktivitätsdaten im Sektor LULUCF in der Schweiz inklusive Begleitdokumentation. Internes Dokument. [GHG inventory, sector LULUCF. Spreadsheets to calculate the activity data of the LULUCF sector in Switzerland inclusive accompanying documents. Internal document]. Sigmaplan, Bern.

SKW 2010: Annual reports of the Swiss Cosmetic and Detergent Association. Zurich. http://www.skw-cds.ch/fileadmin/skwcdsch/02_Kosmetik/JB2012E.pdf [07.02.2014]

Soliva, C.R. 2006: Report to the attention of IPCC about the data set and calculation method used to estimate methane formation from enteric fermentation of agricultural livestock population and manure management in Swiss agriculture. On behalf of the Federal Office for the Environment, Bern. ETH Zurich, Institute of Animal Science.
http://www.bafu.admin.ch/ghginv-ref

Sommer, S.G., Petersen, S.O., Sorensen, P., Poulsen, H.D., Moller, H.B. 2007: Methane and carbon dioxide emissions and nitrogen turnover during liquid manure storage. Nutrient Cycling in Agroecosystems 78 (1): 27-36.

Spicer C.W., Holdren M.W., Riggin R.M., Lyon T.F. 1994: Chemical composition and photochemical reactivity of exhaust from aircraft turbine engines. Annales Geophysicae 12 (10-11): 944-955.
http://dx.doi.org/10.1007/s00585-994-0944-0

Spiecker, H., 1999: Growth trends in European forests, Do we have sufficient knowledge? In Karjalainen T, Spiecker H, Laroussinie, O. (Eds) 1999. Causes and consequences of accelerating tree growth in Europe. Proceedings of the international seminar held in Nancy, France 14–16. May 1998. European Forest Institute Proceedings No. 27: 157-169.

Spiess, E. 2005: Die Stickstoffbilanz der Schweiz. In: Herzog, F., Richner, W. (eds.): Evaluation der Ökomassnahmen Bereich Stickstoff und Phosphor. Schriftenreihe der FAL 57. Zürich Reckenholz: 26-31.

Spiess, E., Prasuhn, V. 2006: Weniger Nitrat im Grundwasser dank Ökomassnahmen. AGRARForschung 13(1): 4-9.

Spirig, C., Neftel, A. 2002: Biogene VOC und Aerosole. Bedeutung der biogenen flüchtigen organischen Verbindungen für die Aerosolbildung. Schriftenreihe der FAL 42. Zürich-Reckenholz.

SQS 2008: IQNet and SQS ISO 9001:2000 Certificate. Certified area: National Inventory System. Field of activity: Greenhouse Gas Inventory and CO_2 Statistics. Registration Number: CH-34433. Issued on 04.01.2008
www.bafu.admin.ch/ghginv-ref

SQS 2010: IQNet and SQS ISO 9001:2008 Certificate. Certified area: National Inventory System and National Registry. Field of activity: Greenhouse Gas Inventory, CO_2 Statistics and Accounting of Kyoto Protocol Units. Registration Number: CH-34433. Issued on 01.12.2010
http://www.bafu.admin.ch/ghginv-ref

Staerfl, S. M., Amelchanka, S. L., Kälber, T., Soliva, C. R., Kreuzer, M., Zeitz, J. O. 2012: Effect of feeding dried high-sugar ryegrass (‘AberMagic’) on methane and urinary nitrogen emissions of primiparous cows. Livestock Science 150(1–3): 293-301.

Stangle, R. 2004: Ingenieurbiologische Hangsicherungsmassnahmen in Wildbacheinzugsgebieten – Bestandesentwicklung und langfristige Wirksamkeit. Klagenfurt: Internationale Forschungsgesellschaft Interpraevent, Tagungspublikation Internationales Symposium Interpraevent 2004, Band 1, pp. 295–305.

Statistics Finland 2014: Greenhouse gas emissions in Finland 1990-2012. National Inventory Report under the UNFCCC and the Kyoto Protocol.

Stehfest, E., Bouwman, L. 2006: N_2O and NO emission from agricultural fields and soils under natural vegetation: summarizing available measurement data and modeling of global annual emissions. Nutrient Cycling in Agroecosystems 74(3): 207-228.

Stieger, J. 2014: Methane emissions at farm and regional scales: origin, magnitude and spatio-temporal variability. PhD Thesis ETHZ; Zürich, Switzerland.

Stricker, B. 2012: Energiebedarfswerte der Pferde, Esel und Ponys. Written communication from Brigitte Stricker (ALP-Haras, Agroscope Liebefeld-Posieux research station) to Daniel Bretscher (ART, Reckenholz), August-October 2012.
http://www.bafu.admin.ch/ghginv-ref

SWI 2009: Forests continue conquest of countryside. Published online 28.07.2009.
http://www.swissinfo.ch/eng/forests-continue-conquest-of-countryside/990884

Swiss Confederation 1983: Loi fédérale du 7 octobre 1983 sur la protection de l’environnement (Loi sur la protection de l’environnement, LPE). As at 01 August 2008.
http://www.admin.ch/ch/f/rs/c814_01.html [official text in German, French and Italian] [27.01.2014]

Swiss Confederation 1985: Ordonnance du 16 décembre 1985 sur la protection de l’air (OPair). [Swiss Federal Ordinance on Air Pollution Control]. As of 01 January 2009: Annex 5
http://www.admin.ch/ch/f/rs/c814_318_142_1.html [official text in German, French and Italian] [10.02.2014]
http://www.bafu.admin.ch/ghginv-ref

Swiss Confederation 1986: Ordonnance du 9 juin 1986 sur les polluants du sol (Ordinance against pollution of soils). In force until 1998; replaced by Swiss Confederation, 1998.

Swiss Confederation 1991: Loi fédérale du 4 octobre 1991 sur les forêts (Loi sur les forêts, LFo). As at 01 July 2013.

http://www.admin.ch/ch/f/rs/c921_0.html [official text in German, French and Italian] [30.03.2015]

Swiss Confederation 1991a: Ordonnance du 21 janvier 1991 sur la protection des hauts-marais et des marais de transition d'importance nationale (Ordonnance sur les hauts-marais). As at 01 January 2008.
http://www.admin.ch/ch/f/rs/c451_32.html [official text in German, French and Italian] [13.03.2013]

Swiss Confederation 1992: Ordonnance du 30 novembre 1992 sur les forêts (OFo). As at 01 March 2011.
http://www.admin.ch/ch/f/rs/c921_01.html [official text in German, French and Italian] [05.04.2011]

Swiss Confederation 1992a: Bundesstatistikgesetz vom 9. Oktober 1992. As of 1.1.2015.
http://www.admin.ch/ch/d/sr/c431_01.html [official text in German, French and Italian] [21.01.2015]

Swiss Confederation 1993: Verordnung über die Durchführung von statistischen Erhebungen des Bundes vom 30. Juni 1993. As of 15. 12. 2014.
http://www.admin.ch/ch/d/sr/c431_012_1.html [official text in German, French and Italian] [21.01.2015]

Swiss Confederation 1994: Ordonnance du 7 septembre 1994 sur la protection des bas-marais d'importance nationale (Ordonnance sur les bas-marais). As at 01 February 2010.
http://www.admin.ch/ch/f/rs/c451_33.html [official text in German, French and Italian] [30.03.2015]

Swiss Confederation 1997: Ordonnance du 12 novembre 1997 sur la taxe d'incitation sur les composés organiques volatils (OCOV). As at 01 January 2009.
http://www.admin.ch/ch/f/rs/c814_018.html [official text in German, French and Italian] [09.02.2015]

Swiss Confederation 1998: Ordonnance du 1er juillet 1998 sur les atteintes portées aux sols (OSol) (Ordinance against deterioration of soils). As at 01 June 2012.
http://www.admin.ch/opc/fr/classified-compilation/19981783/index.html [official text in German, French and Italian] [30.03.2015]

Swiss Confederation 2005: Ordinance of 18 May 2005 on Risk Reduction related to the Use of certain particularly dangerous Substances, Preparations and Articles (Ordinance on Chemical Risk Reduction, ORRChem). SR Number 814.81. As on 1 August 2011.
http://www.admin.ch/ch/d/sr/814_81/index.html [official text in German, French and Italian] [10.02.2014]
http://www.admin.ch/ch/e/rs/8/814.81.en.pdf [inofficial translation in English] [30.03.2015]

Swiss Confederation 2011: Bundesgesetz über die Reduktion der CO_2-Emissionen (CO_2-Gesetz). As of 1.1.2013.
http://www.admin.ch/ch/d/sr/c641_71.html [26.02.2015]

Swiss Confederation 2012: Verordnung über die Reduktion der CO_2-Emissionen (CO_2-Verordnung). As of 12.2.2013.
http://www.admin.ch/ch/d/sr/c641_711.html [26.02.2015]

Swiss Federal Council: Waters Protection Ordinance of 28 October 1998 (Status as of 1 January 2014). SR 814.201
http://www.admin.ch/opc/en/classified-compilation/19983281/index.html [5.12.2014]

Swiss-TS 2013: Quality management according to ISO 9001:2008. Certificate. Certified area: National Inventory System and Reporting under the UNFCCC and the Kyoto Protocol. Registration Number: 13-299-113. Issued on 25.11.2013.
www.bafu.admin.ch/ghginv-ref

Theloke, J. et al. 2000: Ermittlung der Lösemittelemissionen 1994 in Deutschland und Methoden zur Fortschreibung. Institut für Energiewirtschaft und Rationelle Energieanwendung (IER) der Universität Stuttgart.Forschungsbericht 295 42 628. Im Auftrag des Umweltbundesamtes.
http://www.umweltdaten.de/publikationen/fpdf-l/2484.pdf [21.2.2012]

Theloke, J. 2005: NMVOC-Emissionen aus der Lösemittelanwendung und Möglichkeiten zu ihrer Minderung. Fortschritt-Berichte VDI Reihe 15 Nr. 252. Düsseldorf: VDI-Verlag.
http://elib.uni-stuttgart.de/opus/volltexte/2005/2339/ [01.02.2014]

Thürig, E., Kaufmann, E., Schmid, S., Bugmann, H. 2005a: Treibhausgas Inventar: Waldkennzahlen und jährlicher Klimaeinfluss. Internal report to FOEN. Inclusive: Excel-Datei Klimafaktoren.berechnen.xls zur Berechnung des jährlichen klimakorrigierten Zuwachses.
http://www.bafu.admin.ch/ghginv-ref

Thürig, E., Weber, P., Lischke, H., Schmatz, D., Kaufmann, E., Zandt, H., Dobbertin, M., Zingg, A., Cherubini, P., Waldner, P. 2009: Verbesserung der Klimaabhängigkeit der Wachstumsfunktion für Szenarienanalysen der Waldentwicklung (Holznutzungspotential, Nachhaltigkeit) KLIWAWA. [Improvement of climate dependency of growth curves for analyzing forest development scenarios (sustainable Potential Wood Supply]. Forschungsanstalt für Wald, Schnee und Landschaft WSL. Research project on behalf of the Federal Office for the Environment, Bern.
http://www.bafu.admin.ch/ghginv-ref

Thürig, E., Herold, A. 2013: Recalculation of emission factors in Swiss forests for the Swiss GHGI. Internal documentation of technical adjustments of data delivery and more recent data. Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf.
www.bafu.admin.ch/ghginv-ref

Thürig, E., Rösler, E., Didion, M. 2015: NFI 2009–2013: Calculation of emission factors for living biomass in Swiss forests for the Swiss GHGI 2015. Internal documentation of data delivery and more recent data. Report commissioned by the Swiss Federal Office for the Environment.
http://www.bafu.admin.ch/ghginv-CP2-ref

Thuille, A., Schulze, E.D. 2006: Carbon dynamics in successional and afforested spruce stands in Thuringia and the Alps. Global Change Biology 12: 325-342.
http://dx.doi.org/10.1111/j.1365-2486.2005.01078.x

TTM 2006a: Emissionsfaktoren CH_4, TTM, A. Mayer 16.1.2006
http://www.bafu.admin.ch/ghginv-ref

TTM 2006b: Emissionsfaktoren N_2O, TTM, A. Mayer 16.1.2006
http://www.bafu.admin.ch/ghginv-ref

Tuomi, M., Thum, T., Järvinen, H., Fronzek, S., Berg, B., Harmon, M., Trofymow,J.A., Sevanto, S., Liski, J. 2009: Leaf litter decomposition - Estimates of global variability based on Yasso07 model. Ecological Modelling 220: 3362-3371. http://dx.doi.org/10.1016/j.ecolmodel.2009.05.016

Tuomi, M., Laiho, R., Repo, A., Liski, J. 2011: Wood decomposition model for boreal forests. Ecological Modelling 222: 709-718. http://dx.doi.org/10.1016/j.ecolmodel.2010.10.025

UBA 2005: Emissionen, Aktivitätsraten und Emissionsfaktoren von fluorierten Treibhausgasen (F-Gasen) in Deutschland für die Jahre 1995 – 2002. Texte: 14 / 05. Umwelt Bundes Amt. Berlin. http://www.umweltbundesamt.de/publikationen/methoden-indikatorenentwicklung-fuer-kenndaten [31.03.2015]

UBA 2006: Einsatz von Sekundärbrennstoffen, Forschungsbericht 204 42 203/02, UBA-FB 000893; available for download from www.umweltbundesamt.de

UBA 2007: Daten von H-FKW, FKW und SF6 für die nationale Emissionsberichterstattung gemäß Klimarahmenkonvention für die Berichtsjahre 2004 und 2005“ "Fluorierte Treibhausgase". Gutachten durch die Oeko-Recherche GmbH für das Umweltbundesamt (FKZ 205 41 217/01), Frankfurt. http://www.umweltbundesamt.de/sites/default/files/medien/publikation/long/3439.pdf [31.03.2015]

UBA/Ökorecherche 2012: Entsorgung von Kältemitteln aus stationären Anlagen, Emissionsfaktor der Entsorgung, Emissionsberichterstattung von F-Gasen in der Kälte- und Klimatechnik. UBA Umweltbundesamt Berlin – 24.10.12. Öko-Recherche Büro für Umweltforschung und -beratung GmbH, W. Schwarz, Barbara Gschrey. Umweltbundesamt Berlin - 24. Oktober 2012, Ergebnisse des Forschungsvorhabens 1. Gewerbekälte und 2. Industriekälte http://www.umweltbundesamt.de/sites/default/files/medien/419/dokumente/4_entsorgung_statanlagen1.pdf [31.03.2015]

Umweltbundesamt 2012: Austria’s National Inventory Report 2012. Submission under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol. Anderl, M et al. REP-0381. http://www.umweltbundesamt.at/fileadmin/site/publikationen/REP0381.pdf [27.03.2013]

UNFCCC 2007: Report of the individual review of the greenhouse gas inventory of Switzerland submitted in 2006. FCCC/ARR/2006/CHE, 31 July 2007. http://unfccc.int/resource/docs/2007/arr/che.pdf[10.02.2015]

UNFCCC 2009: Report of the individual review of the greenhouse gas inventories of Switzerland submitted in 2007 and 2008. FCCC/ARR/2008/CHE, 29 April 2009. http://unfccc.int/resource/docs/2009/arr/che.pdf [10.02.2015]

UNFCCC 2011: Report of the individual review of the annual submission of Switzerland submitted in 2010. FCCC/ARR/2010/CHE, 23 May 2011. http://unfccc.int/resource/docs/2011/arr/che.pdf [27.01.2014]

UNFCCC 2011a: Report of the technical assessment of the forest management reference level submission of Switzerland submitted in 2011 (FCCC/TAR/2011/CHE). Published online

on 21 September 2011.
http://unfccc.int/resource/docs/2011/tar/che01.pdf [26.02.2015]

UNFCCC 2013c: Approved small scale baseline and monitoring methodology AMS-III.D./Version 19.0. Methane recovery in animal manure management systems. Online: http://cdm.unfccc.int/methodologies/DB/3EN93QE1QXUOEVRVV0DRT1EF3Z5SDH [02.02.2013]

UNFCCC 2014: Report of the individual review of the annual submission of Switzerland submitted in 2013. FCCC/ARR/2013/CHE, 28 February 2014.
http://unfccc.int/resource/docs/2013/arr/che.pdf [10.02.2015]

UNFCCC 2014a: Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention. Decision 24/CP.19 (FCCC/CP/2013/10/Add.3)
http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf [21.01.2015]

UNFCCC 2014b: Guidance for reporting information on activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol. Decision 6/CMP.9 (FCCC/KP/CMP/2013/9/Add.1)
http://unfccc.int/resource/docs/2013/cmp9/eng/09a01.pdf [21.01.2015]

UNFCCC 2014c: Report of the individual review of the annual submission of Switzerland submitted in 2014. FCCC/ARR/2014/CHE, 30 December 2014.
http://unfccc.int/resource/docs/2015/arr/che.pdf [10.02.2015]

UNFCCC 2014d: Potential Problems and Further Questions from the ERT formulated in the course of the 2014 review of the greenhouse gas inventories of Party submitted in 2014. Bonn, 06 September 2014.

UNFCCC 2015: Guidelines for the technical review of information reported under the Convention related to greenhouse gas inventories, biennial reports and national communications by Parties included in Annex I to the Convention. Decision -/CP.20 (advance unedited version) (FCCC/CP/201X/XX/xxx)
http://unfccc.int/files/meetings/lima_dec_2014/decisions/application/pdf/auv_cop20_aireviewgdls.pdf [21.01.2015]

USEPA 1995: Compilation of air pollutant emission factors, Chapter 10.7 Charcoal.
http://www.epa.gov/ttn/chief/ap42/index.html [09.12.2014]

USEPA 1995a: US EPA 1995, “Emission factors for open burning of municipal refuse”,
http://www.epa.gov/ttn/chief/ap42/ch02/final/c02s05.pdf [26.02.2015]

UVEK 2003: Düngen mit Klärschlamm wird verboten, UVEK Eidgenössisches Departement für Umwelt, Verkehr, Energie, Kommunikation.
http://www.admin.ch/cp/d/3e816ebe_1@presse1.admin.ch.html [28.02.2013]

Van der Weerden, T.J., Jarvis, S.C. 1997: Ammonia emission factors for N fertilizers applied to two contrasting grassland soils. Environmental Pollution 95(2): 205-211.
http://dx.doi.org/10.1016/S0269-7491(96)00099-1

Van der Zaag, A. C., MacDonald, J. D., Evans, L., Vergé, X. P. C., Desjardins, R. L., 2013: Towards an inventory of methane emissions from manure management that is responsive to changes on Canadian farms. Environmental Research Letters 8(3): 035008.

Van Dorland, H. A., Wettstein, H. R., Leuenberger, H., Kreuzer, M. 2007: Effect of supplementation of fresh and ensiled clovers to ryegrass on nitrogen loss and methane emission of dairy cows. Livestock Science 111(1–2): 57-69.

Van Miegroet, H., Olsson, M. 2011: Ecosystem Disturbance and Soil Organic Carbon – A Review. In: Soil Carbon in Sensitive European Ecosystems. John Wiley & Sons, Ltd, Chichester: 85-117.
http://dx.doi.org/10.1002/9781119970255.ch5

Vanninen, P., Mäkelä, A. 1999: Fine root biomass of Scots pine stands differing in age and soil fertility in southern Finland. Tree Physiology 19: 823–830.
http://dx.doi.org/10.1093/treephys/19.12.823

Verge, X. P. C., De Kimpe, C., Desjardins, R. L. 2007: Agricultural production, greenhouse gas emissions and mitigation potential. Agricultural and Forest Meteorology 142(2-4): 255-269.

Vermorel, M., Martin-Rosset, W., Vernet, J. 1997: Energy utilization of twelve forages or mixed diets for maintenance by sport horses. Livestock Production Science 47(2): 157-167.

Vesterdal, L., Ritter, E., Gundersen, P. 2002: Change in soil organic carbon following afforestation of former arable land. Forest Ecology and Management 169: 137-147.
http://dx.doi.org/10.1016/S0378-1127(02)00304-3

Vorreiter, L. 1949: Holztechnologisches Handbuch; Band I: Allgemeines, Holzkunde, Holzschutz und Holzvergütung. Verlag Georg Fromme & Co., Wien.

VTI 2011: Review of the LULUCF Sector of Switzerland's Greenhouse Gas Inventory 1990-2008. Johann Heinrich von Thünen-Institut, Braunschweig.
http://www.bafu.admin.ch/ghginv-ref

VTT 2004: Transit Bus Emission Study: Comparison of Emissions from Diesel and Natural Gas Buses. Research Report PRO3/P5150/04. VTT Processes, Espoo.
http://www.bafu.admin.ch/ghginv-ref

Walther U., Menzi, H., Ryser, J.-P., Flisch, R., Jeangros, B., Maillard, A., Siegenthaler, A., Vuilloud, P.A. 1994: Grundlagen für die Düngung im Acker- und Futterbau. Agrarforschung 1(7): 1-40.
http://www.bafu.admin.ch/ghginv-ref

Warneke C., Luxembourg, S.L., de Gouw, J.A., Rinne, H.J.I., Guenther, A.B., Fall, R. 2002: Disjunct eddy covariance measurements of oxygenated VOC fluxes from an Alfalfa field before and after cutting. Journal of Geophysical Research 107 D8: 4067.
http://dx.doi.org/10.1029/2001JD000594

Widmer, A. 2006: Written communication from Albert Widmer (Forschungsanstalt Wädenswil) to Jens Leifeld (ART, Reckenholz), 20.06.2006.
http://www.bafu.admin.ch/ghginv-ref

Wiesen, P., Kleffmann, J., Kurtenbach, R., Becker, K.H. 1994: Nitrous Oxide and Methane Emissions from Aero Engines. Geophysical Research Letters 21: 2027-2030.
http://dx.doi.org/10.1029/94GL01709

Wirth, C., Schulze, E. D., Schwalbe, G., Tomczyk, I., Weber, G.-E., Weller, E. 2004: Dynamik der Kohlenstoffvorräte in den Wäldern Thüringens: Abschlussbericht zur 1. Phase des BMBF-Projektes "Modelluntersuchung zur Umsetzung des Kyoto-Protokolls". Mitteilungen der Thüringer Landesanstalt für Wald, Jagd und Fischerei 23.

Wüst, C., Leifeld, J., Grünig, A. 2015: Locating organic soils for the Greenhouse Gas Inventory. Agroscope, Zürich.
www.bafu.admin.ch/ghginv-CP2-ref

Wutzler, T., Wirth, C., Schumacher, J., 2008: Generic biomass functions for common beech (Fagus sylvatica) in Central Europe: predictions and components of uncertainty. Canadian Journal of Forest Research 38: 1661-1675.
http://dx.doi.org/10.1139/X07-194

Xinmin, J. 2004: Die Methanemissionen der Schweizer Gasindustrie. Abschätzung der Gasemissionen [Methane emissions from Swiss gas industry. Estimation of methane emissions]. Gas, Wasser, Abwasser 5/2004: 337-345.
http://www.bafu.admin.ch/ghginv-ref

Zell, J., Thürig, E. 2013: Root biomass functions for for the GHG reporting under the UNFCCC and under the KP in Switzerland. Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf. Internal report to FOEN.

Zeitz, J. O., Soliva, C. R., Kreuzer, M. 2012: Swiss diet types for cattle: how accurately are they reflected by the Intergovernmental Panel on Climate Change default values? Journal of Integrative Environmental Sciences, 9:sup1,199-216.
http://dx.doi.org/10.1080/1943815X.2012.709253

Zimmermann, M., Leifeld, J., Schmidt, M.W.I., Smith, P., Fuhrer, J. 2007: Measured soil organic matter fractions can be related to pools in the RothC model. European Journal of Soil Science 58: 658–667.
http://dx.doi.org/10.1111/j.1365-2389.2006.00855.x

Zimmermann, S., Hiltbrunner, D. 2012: Turnover and stabilization of soil organic matter: effect of land-use change in alpine regions. Schlussbericht [German]. Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf.
http://www.bafu.admin.ch/ghginv-ref

ZPK 2014: Annual Report of Federation of the Swiss Pulp, paper and board industry.
http://www.zpk.ch/ [25.11.2014]

References to EMIS database comments

Table A – 43 Assignments of NFR Codes to titles of EMIS database comments. These internal documents will be made available to reviewers on request.

NFR Code CRF [UNECE]	EMIS Title	NFR Code CRF [UNE	EMIS Title
1 A 1 a	Kehrichtverbrennungsanlagen	2 D 3 a [2 D 3 g]	Klebstoff-Produktion
1 A 1 a	Sondermüllverbrennungsanlagen	2 D 3 a [2 D 3 g]	Lösungsmittel-Umschlag und -Lager
1 A 1 a & 5 A	Kehrichtdeponien	2 D 3 a [2 D 3 g]	Pharmazeutische Produktion**
1 A 1 a & 5 B 2	Vergärung IG (industriell-gewerblich)	2 D 3 a [2 D 3 g]	Polyester-Verarbeitung
1 A 1 a & 5 B 2	Vergärung LW (landwirtschaftlich)	2 D 3 a [2 D 3 g]	Polystyrol-Verarbeitung
1 A 1 c	Holzkohle Produktion	2 D 3 a [2 D 3 g]	Polyurethan-Verarbeitung
1 A 2 a	Eisengiessereien Kupolöfen	2 D 3 a [2 D 3 g]	PVC-Verarbeitung
1 A 2 a	Stahl-Produktion Wärmeöfen**	2 D 3 a [2 D 3 g]	Gerben von Ledermaterialien
1 A 2 b	Buntmetallgiessereien übriger Betrieb**	2 D 3 b	Strassenbelagsarbeiten**
1 A 2 b & 2 C 3	Aluminium Produktion	2 D 3 c	Dachpappen Produktion Emissionen aus Bitumen
1 A 2 c & 2 B 8 b [2 B 10 a]	Ethen-Produktion*	2 D 3 c	Dachpappen Produktion Voranstrich
1 A 2 d	Zellulose-Produktion Feuerung*	2 D 3 c	Dachpappen Verlegung Bitumen
1 A 2 f	Kalkproduktion, Feuerung*	2 D 3 c	Dachpappen Verlegung Voranstrich
1 A 2 f	Mischgut Produktion	2 D 3 d	Urea (AdBlue) Einsatz Strassenverkehr
1 A 2 f	Zementwerke Feuerung	2 G 3 a	Lachgasanwendung Spitäler**
1 A 2 f & 2 A 3	Glas übrige Produktion*	2 G 3 b	Lachgasanwendung Haushalt**
1 A 2 f & 2 A 3	Glaswolle Produktion Rohprodukt*	2 G 4 [2 D 3 a]	Pharma-Produkte im Haushalt
1 A 2 f & 2 A 3	Hohlglas Produktion*	2 G 4 [2 D 3 a]	Reinigungs- und Lösemittel; Haushalte
1 A 2 f & 2 A 4 a	Feinkeramik Produktion*	2 G 4 [2 D 3 a]	Spraydosen Haushalte**
1 A 2 f & 2 A 4 a	Ziegeleien**	2 G 4 [2 D 3 h]	Verpackungsdruckereien**
1 A 2 f & 2 A 4 d	Steinwolle Produktion*	2 G 4 [2 D 3 h]	Druckereien
1 A 2 g iv	Faserplatten Produktion**	2 G 4 [2 D 3 i]	Entfernung von Farben und Lacken
1 A 3 a & 1 A 5	Flugverkehr	2 G 4 [2 D 3 i]	Entwachsung von Fahrzeugen
1 A 3 b i-viii	Strassenverkehr	2 G 4 [2 D 3 i]	Kosmetika-Produktion**
1 A 3 c	Schienenverkehr	2 G 4 [2 D 3 i]	Lösungsmittel-Emissionen IG nicht zugeordnet
1 A 3 e	Gastransport Kompressorstation	2 G 4 [2 D 3 i]	Öl- und Fettgewinnung
1 A 4 b i	Holzkohle-Verbrauch	2 G 4 [2 D 3 i]	Papier- und Karton-Produktion**
1 A 4 b i	Lagerfeuer	2 G 4 [2 D 3 i]	Parfum- und Aromen-Produktion**
1 A 4 c i	Grastrocknung**	2 G 4 [2 D 3 i]	Tabakwaren Produktion**
1 B 2 a iv	Raffinerie, Leckverluste	2 G 4 [2 D 3 i]	Textilien-Produktion
1 B 2 a v	Benzinumschlag Tanklager	2 G 4 [2 D 3 i]	Wissenschaftliche Laboratorien
1 B 2 a v	Benzinumschlag Tankstellen	2 G 4 [2 G]	Korrosionsschutz im Freien
1 B 2 b ii	Gasproduktion	2 G 4 [2 G]	Betonzusatzmittel-Anwendung
1 B 2 b iv-vi	Netzverluste Erdgas	2 G 4 [2 G]	Coiffeursalons
1 B 2 c	Raffinerie, Abfackelung	2 G 4 [2 G]	Fahrzeug-Unterbodenschutz**
1 Energy Model***	Energie New	2 G 4 [2 G]	Feuerwerke
1A	Holzfeuerungen	2 G 4 [2 G]	Flugzeug-Enteisung
1A2g vii-viii, 1A3c, 1A3e, 1A5b (ohne Luftfahrt Militär)	Off-Road	2 G 4 [2 G]	Gas-Anwendung
2 A 1	Zementwerke Rohmaterial	2 G 4 [2 G]	Gesundheitswesen, übrige**
2 A 1	Zementwerke übriger Betrieb	2 G 4 [2 G]	Glaswolle Imprägnierung*
2 A 2	Kalkproduktion, Rohmaterial*	2 G 4 [2 G]	Holzschutzmittel-Anwendung
2 A 2	Kalkproduktion, übriger Betrieb*	2 G 4 [2 G]	Klebstoff-Anwendung
2 A 4 d	Karbonatanwendung weitere	2 G 4 [2 G]	Kosmetik-Institute
2 A 5 a	Gips-Produktion übriger Betrieb**	2 G 4 [2 G]	Kühlschmiermittel-Verwendung
2 B 1	Ammoniak-Produktion*	2 G 4 [2 G]	Medizinische Praxen**
2 B 10 [2 B 10 a]	Ammoniumnitrat-Produktion*	2 G 4 [2 G]	Pflanzenschutzmittel-Verwendung
2 B 10 [2 B 10 a]	Chlorgas-Produktion*	2 G 4 [2 G]	Reinigung Gebäude IGD**
2 B 10 [2 B 10 a]	Essigsäure-Produktion*	2 G 4 [2 G]	Schmierstoff-Verwendung
2 B 10 [2 B 10 a]	Formaldehyd-Produktion	2 G 4 [2 G]	Spraydosen IndustrieGewerbe
2 B 10 [2 B 10 a]	PVC-Produktion	2 G 4 [2 G]	Tabakwaren Konsum
2 B 10 [2 B 10 a]	Salzsäure-Produktion*	2 G 4 [2 G]	Steinwolle-Imprägnierung*
2 B 10 [2 B 10 a]	Schwefelsäure-Produktion*	2 H 1	Faserplatten Produktion**
2 B 10	Kalksteingrube*	2 H 1	Zellulose Produktion übriger Betrieb*
2 B 10	Niacin-Produktion*	2 H 1	Spanplatten Produktion*
2 B 2	Salpetersäure Produktion*	2 H 2	Bierbrauereien
2 B 4	Graphit und Siliziumkarbid Produktion*	2 H 2	Branntwein Produktion
2 C - 2 G	Synthetische Gase	2 H 2	Brot Produktion
2 C 1	Eisengiessereien Elektroschmelzöfen	2 H 2	Fleischräuchereien
2 C 1	Eisengiessereien übriger Betrieb	2 H 2	Kaffeeröstereien
2 C 1	Stahl-Produktion Elektroschmelzöfen**	2 H 2	Müllereien
2 C 1	Stahl-Produktion übriger Betrieb**	2 H 2	Wein Produktion
2 C 1	Stahl-Produktion Walzwerke**	2 H 2	Zucker Produktion
2 C 6	Verzinkereien	2 H 3	Sprengen und Schiessen
2 C 7 a	Buntmetallgiessereien Elektroöfen**	2 I	Holzbearbeitung
2 C 7 c	Batterie-Recycling*	3	Landwirtschaft
2 D 1	Schmiermittel-Anwendung	3 C	Reisanbau
2 D 2	Paraffinwachs-Anwendung	5 B 1	Kompostierung Industrie
2 D 3 a [2 D 3 d]	Farben-Anwendung Bau	5 B 1	Kompostierung, Verbreitung als Dünger im Haushalt
2 D 3 a [2 D 3 d]	Farben-Anwendung andere	5 B 2	Biogasaufbereitung (Methanverlust)
2 D 3 a [2 D 3 d]	Farben-Anwendung Haushalte**	5 C 1 [5 C 1 a]	Abfallverbrennung illegal
2 D 3 a [2 D 3 d]	Farben-Anwendung Holz	5 C 1 [5 C 1 b i]	Kabelabbrand
2 D 3 a [2 D 3 d]	Farben-Anwendung Autoreparatur	5 C 1 [5 C 1 b iii]	Spitalabfallverbrennung
2 D 3 a [2 D 3 e]	Elektronik-Reinigung	5 C 1 [5 C 1 b iv]	Klärschlammverbrennung
2 D 3 a [2 D 3 e]	Metallreinigung	5 C 1 [5 C 1 b v]	Krematorien
2 D 3 a [2 D 3 e]	Reinigung Industrie übrige	5 C 2	Abfallverbrennung Land- und Forstwirtschaft
2 D 3 a [2 D 3 f]	Chemische Reinigung**	5 D 1 [5 D]	Kläranlagen kommunal (Luftschadstoffe)
2 D 3 a [2 D 3 g]	Druckfarben Produktion	5 D 2 [5 D]	Kläranlagen industriell (Luftschadstoffe)
2 D 3 a [2 D 3 g]	Farben-Produktion	5 D 1 / 5 D 2 [5 D]	Kläranlagen GHG
2 D 3 a [2 D 3 g]	Feinchemikalien-Produktion**	5 E	Shredder Anlagen
2 D 3 a [2 D 3 g]	Gummi-Verarbeitung**	6 A d	Brand- und Feuerschäden Immobilien
2 D 3 a [2 D 3 g]	Klebband-Produktion	6 A d	Brand- und Feuerschäden Motorfahrzeuge

* confidential process
** confidential EMIS comment
*** work in progress